IN-FLIGHT INVESTIGATION OF AN UNAUGMENTED CLASS III AIRPLANE IN THE LANDING APPROACH TASK
PHASE I – LATERAL-DIRECTIONAL STUDY

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FOREWORD

This final technical report was prepared by the Cornell Aeronautical Laboratory, Inc. (CAL), Buffalo, New York, in partial fulfillment of Item 2 of Contract F33615-71-C-1110. The work was performed under Project 684B, "Extensive Checkout of the Variable Stability System in the TIFS Airplane." J. R. Pruner (AFFDL/FGC) was Project Engineer for the Air Force Flight Dynamics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.

The work reported here was performed by the Flight Research Department of the Cornell Aeronautical Laboratory, Inc. Dr. P. A. Reynolds was Program Manager, Mr. G. J. Fabian was the Assistant Program Manager and Mr. Richard Wasserman was Project Engineer. Acknowledgment is given to Mr. Gifford Bull of CAL, Mr. Russell Scott of North American Aviation, and Mr. Glenn Stennett of NASA who were the evaluation pilots on this program.

The successful completion of this investigation is largely due to the excellent team performance of the TIFS flight crew who are especially acknowledged here. Crew Chiefs: Raymond Miller and David Kostrubanic; Safety Pilots: Nello Infanti, Franklin Eckhart and Edward Boothe; Test Engineers: James Dittenhauser, David Begier, Arno Schelhorn, Ralph Siracuse, and Ronald Huber.

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ABSTRACT

An in-flight research program on the handling qualities of Class III airplanes in the landing approach was conducted using the USAF/CAL Total In-Flight Simulator (TIFS) airplane. This was the first research program utilizing the TIFS airplane. For this program, the TIFS was used in the model-following mode and its capability as a research facility for handling qualities investigation was clearly demonstrated. The Phase I research program discussed in this report consisted of an investigation of lateral-directional handling qualities. A baseline configuration was defined by a set of stability and control derivatives provided by the Air Force. The experiment was based on the evaluation of this configuration and other configurations defined by changes in stability and control derivatives from the baseline values. Seventeen different configurations were evaluated utilizing 3 different pilots. A total of thirty six evaluations was performed. For the configurations evaluated (typically characterized by a low frequency Dutch roll mode with low roll to yaw ratios and an unstable spiral mode), the indicated level of handling qualities defined by the $\Delta\beta_{max}/k$ requirement (3.3.2.4.1) of MIL-F-8785B(ASG) correlated quite well with the pilot ratings obtained in this investigation. The data obtained in this program indicates the need for modification of the lateral-directional handling qualities requirements of MIL-F-8785B(ASG) for airplanes with long period and low roll to yaw ratio Dutch roll dynamics, with unstable spiral mode, in Flight Phase Category C.

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b	Reference span of wing, feet
$\bar{c}$	Mean aerodynamic chord, feet
C_D	Drag coefficient, $= D/\bar{q}S$
C_{D_0}	Drag coefficient at zero lift
C_ℓ	Rolling moment coefficient, $= L/\bar{q}Sb$
C_{ℓ_p}	$= \partial C_\ell / \partial\left(\frac{pb}{2V}\right)$, rad^{-1}
C_{ℓ_r}	$= \partial C_\ell / \partial\left(\frac{rb}{2V}\right)$, rad^{-1}
C_{ℓ_β}	$= \partial C_\ell / \partial\beta$, rad^{-1}
$C_{\ell_{\delta_a}}$	$= \partial C_\ell / \partial\delta_a$, rad^{-1}
$C_{\ell_{\delta_r}}$	$= \partial C_\ell / \partial\delta_r$, rad^{-1}
C_L	= Lift coefficient, $= L/\bar{q}S$
$C_L\|_{\alpha=0}$	= Lift coefficient at zero angle of attack
C_{L_q}	$= \partial C_L / \partial\left(\frac{q\bar{c}}{2V}\right)$, rad^{-1}
C_{L_α}	$= \partial C_L / \partial\alpha$, rad^{-1}
$C_{L_{\dot\alpha}}$	$= \partial C_L / \partial\left(\frac{\dot\alpha\bar{c}}{2V}\right)$, rad^{-1}
$C_{L_{\delta_e}}$	$= \partial C_L / \partial\delta_e$, rad^{-1}
C_m	Pitching moment coefficient, $= M/\bar{q}S\bar{c}$
$C_m\|_{\alpha=0}$	Pitching moment coefficient at zero angle of attack
C_{m_q}	$= \partial C_m / \left(\frac{q\bar{c}}{2V}\right)$, rad^{-1}
C_{m_α}	$= \partial C_m / \partial\alpha$, rad^{-1}
$C_{m_{\dot\alpha}}$	$= \partial C_m / \partial\left(\frac{\dot\alpha\bar{c}}{2V}\right)$, rad^{-1}
$C_{m_{\delta_e}}$	$= \partial C_m / \partial\delta_e$, rad^{-1}
C_n	Yawing moment coefficient, $= N/\bar{q}Sb$
C_{n_p}	$= \partial C_n / \left(\frac{pb}{2V}\right)$, rad^{-1}

C_{n_r}	$= \partial C_n / \partial \left(\frac{rb}{2V}\right)$, rad^{-1}
C_{n_β}	$= \partial C_n / \partial \beta$, rad^{-1}
$C_{n_{\delta_a}}$	$= \partial C_n / \partial \delta_a$, rad^{-1}
$C_{n_{\delta_r}}$	$= \partial C_n / \partial \delta_r$, rad^{-1}
C_y	= Lateral force coefficient, $= Y/\bar{q}S$
C_{y_β}	$= \partial C_y / \partial \beta$, rad^{-1}
$C_{y_{\delta_a}}$	$= \partial C_y / \partial \delta_a$, rad^{-1}
$C_{y_{\delta_r}}$	$= \partial C_y / \partial \delta_r$, rad^{-1}
C_z	z -force coefficient, $= Z/\bar{q}S$
D	Drag, positive along negative x wind axis, lb
F_{AW}	Aileron wheel force, lb
F_{EW}	Elevator wheel force, lb
F_{RP}	Rudder pedal force, lb
g	Gravitational constant, 32.17 ft/sec^2
h	Absolute altitude, ft
I_{xx}	Moments of inertia about x, y, z body axes, respectively, slug-ft^2
I_{yy}	
I_{zz}	
I_{xz}	Product of inertia about x, z body axes, slug-ft^2

k	ratio of "commanded roll performance" to applicable roll performance requirement" of 3.3.4 or 3.3.4.1 of MIL-F-8785B(ASG), where: (a) "Applicable roll performance requirement", $\phi_{t_{\text{requirement}}}$, is determined from 3.3.4 and 3.3.4.1 of MIL-F-8785B(ASG) for the Class, Flight Phase Category and Level under consideration. (b) "Commanded roll performance", $\phi_{t_{\text{command}}}$, is the bank angle attained in the stated time for a given step aileron command with rudder pedals employed as specified in 3.3.4 and 3.3.4.1 of MIL-F-8785B(ASG). $k = \dfrac{(\phi_t)_{command}}{(\phi_t)_{requirement}}$
l_x	Distance from the c.g. to a point on the x body axis, positive along positive x axis, ft
l_z	Distance from the c.g. to a point on the z body axis, positive along positive z axis, ft
L	Lift, positive along negative z wind axis, lb
L	Rolling moment about x body axis, ft-lb
L'_r	$= \left(1 - \dfrac{I_{xz}^2}{I_x I_z}\right)^{-1} \left(L_r + \dfrac{I_{xz}}{I_x} N_r\right)$
L'_β	$= \left(1 - \dfrac{I_{xz}^2}{I_x I_z}\right)^{-1} \left(L_\beta + \dfrac{I_{xz}}{I_x} N_\beta\right)$
L'_{δ_a}	$= \left(1 - \dfrac{I_{xz}^2}{I_x I_z}\right)^{-1} \left(L_{\delta_A} + \dfrac{I_{xz}}{I_x} N_{\delta_a}\right)$
m	Mass of aircraft, slugs
M	Pitching moment about y body axis, ft-lb

n_x	Longitudinal acceleration, g units
n_y	Lateral acceleration, g units
n_z	Normal acceleration, g units
N	Yawing moment about z body axis, ft-lb
N'_p	$= \left(1 - \frac{I_{xz}^2}{I_x I_z}\right)^{-1} \left(N_p + \frac{I_{xz}}{I_z} L_p\right)$
N'_{δ_a}	$= \left(1 - \frac{I_{xz}^2}{I_x I_z}\right)^{-1} \left(N_{\delta_a} + \frac{I_{xz}}{I_z} L_{\delta_a}\right)$
p	Roll rate, deg/sec
p_{osc}/p_{AV}	A measure of the ratio of the oscillatory component of roll rate to the average component of roll rate following a rudder-pedals-free step aileron control command: $\zeta \leq 0.2: \quad \frac{p_{osc}}{p_{AV}} = \frac{p_1 + p_3 - 2p_2}{p_1 + p_3 + 2p_2}$ $\zeta \geq 0.2: \quad \frac{p_{osc}}{p_{AV}} = \frac{p_1 - p_2}{p_1 + p_2}$ where p_1, p_2 and p_3 are roll rates at the first, second and third peaks, respectively.
$\measuredangle p/\beta$	Phase angle between roll rate and sideslip in the free Dutch roll oscillation. Angle is positive when p leads β by an angle between 0 and 180°
q	Pitch rate, deg/sec
$\bar{q}$	Dynamic pressure, $= 1/2 \rho V^2$, lb/ft^2
r	Yaw rate, deg/sec
S	Reference area of wing, ft^2
t	Time, seconds
T	Total thrust of aircraft, lb
T_{2_s}	Time to double amplitude of the spiral mode, sec
u	True airspeed component along the x body axis, ft/sec

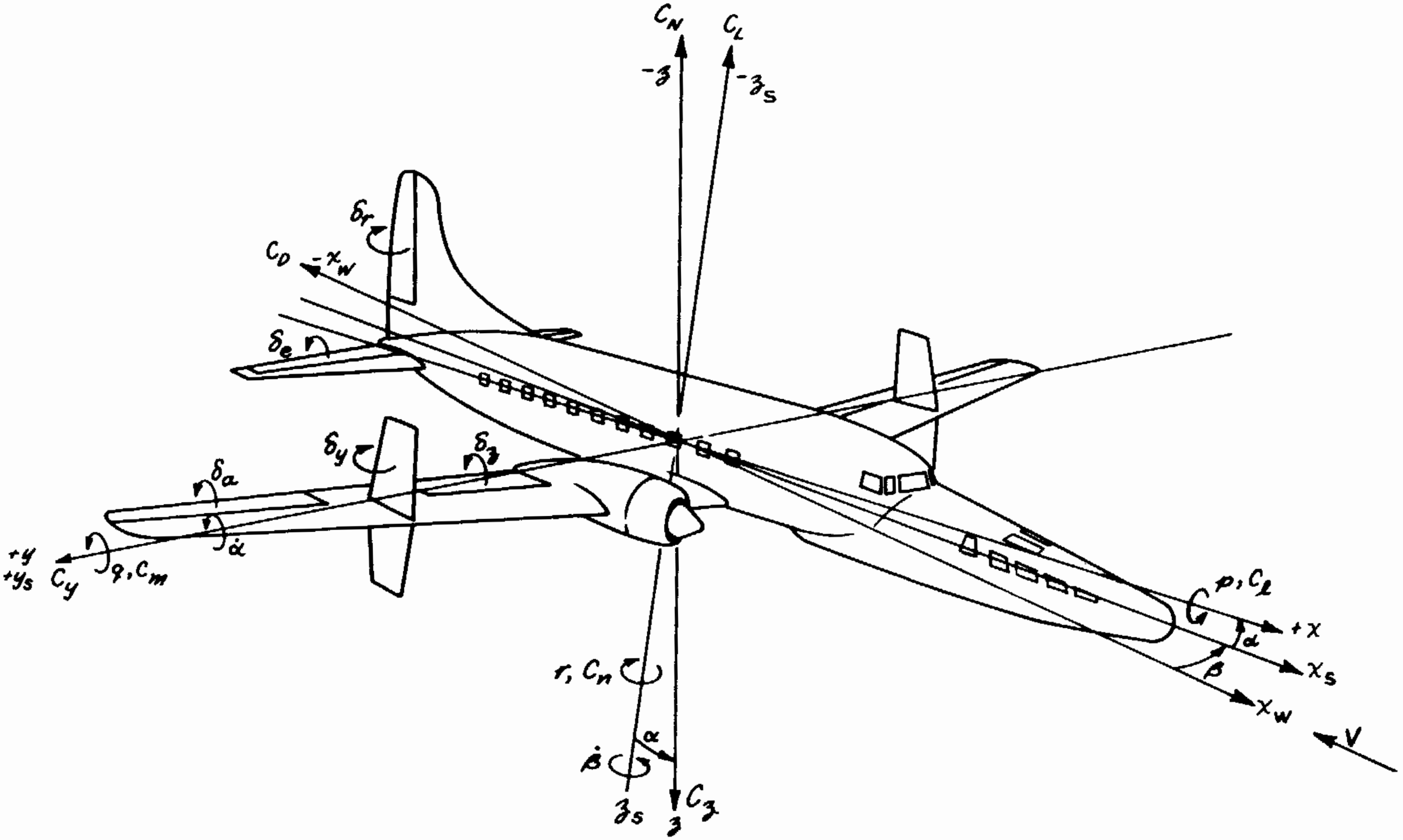
u_I	Inertial velocity component along the x body axis, ft/sec
v	True airspeed component along the y body axis, ft/sec
v_I	Inertial velocity component along the y body axis, ft/sec
V	True airspeed of the c.g. of the aircraft, ft/sec
V_I	Inertial airspeed of the aircraft in earth surface axes, ft/sec
W	Aircraft weight, lb
w	True airspeed component along the z body axis, ft/sec
w_I	Inertial velocity component along the z body axis, ft/sec
x, y, z	Body axes, x-z plane is in the plane of symmetry of the airplane with x directed forward parallel to the fuselage reference line, z directed downward, and y directed out the right wing.
x_w, y_w, z_w	Wind axes, orthogonal and positive axis system according to the right-hand rule, where x_w is along the velocity vector of airplane with respect to air. The wind axes become fixed in perturbation analysis, their positions given by reference values of α and β.
X, Y, Z	Component of aerodynamic forces along the x, y, and z body axes, respectively, lb
x_T	Thrust pitching moment arm component (positive along +x body axis measured relative to the c.g.), ft

$\bar{y}$	Location of effective yawing moment due to thrust offset, ft
z_T	Thrust pitching moment arm component (positive along $+z$ body axis measured relative to the c.g.), ft
α	Total angle of attack, with respect to true airspeed, deg
α_g	Gust angle of attack, $\alpha_g \equiv \frac{w_g}{V}$ and $\alpha_g = \alpha - \alpha_I$ for small angles, deg
α_I	Inertial angle of attack referenced to inertial velocity vector, deg
β	Total angle of sideslip with respect to true airspeed, deg
β_g	Gust angle of sideslip, $\beta_g \equiv \frac{v_g}{V}$ and $\beta_g = \beta - \beta_I$ for small angles, deg
β_I	Inertial angle of sideslip, referenced to inertial velocity vector, deg
$\Delta\beta_{max}$	Maximum sideslip excursion at the c.g., occurring within two seconds or one half-period of the Dutch roll, whichever is greater, for a step aileron-control command
γ	Flight path angle, deg
δ_a	Total aileron deflection, positive right T.E. down, deg
δ_{AW}	Aileron wheel deflection, positive wheel clockwise, deg
δ_e	Elevator deflection, positive T.E. down, deg
δ_{EW}	Elevator wheel deflection, positive wheel aft, deg
δ_r	Rudder deflection, positive T.E. left, deg
δ_{RP}	Rudder pedal deflection, positive right rudder pedal down, in.
δ_T	Throttle displacement in cockpit, positive forward, deg
ζ_d	Damping ratio of the Dutch roll mode
ζ_{ph}	Damping ratio of the phugoid mode
ζ_{sp}	Damping ratio of the longitudinal short period mode

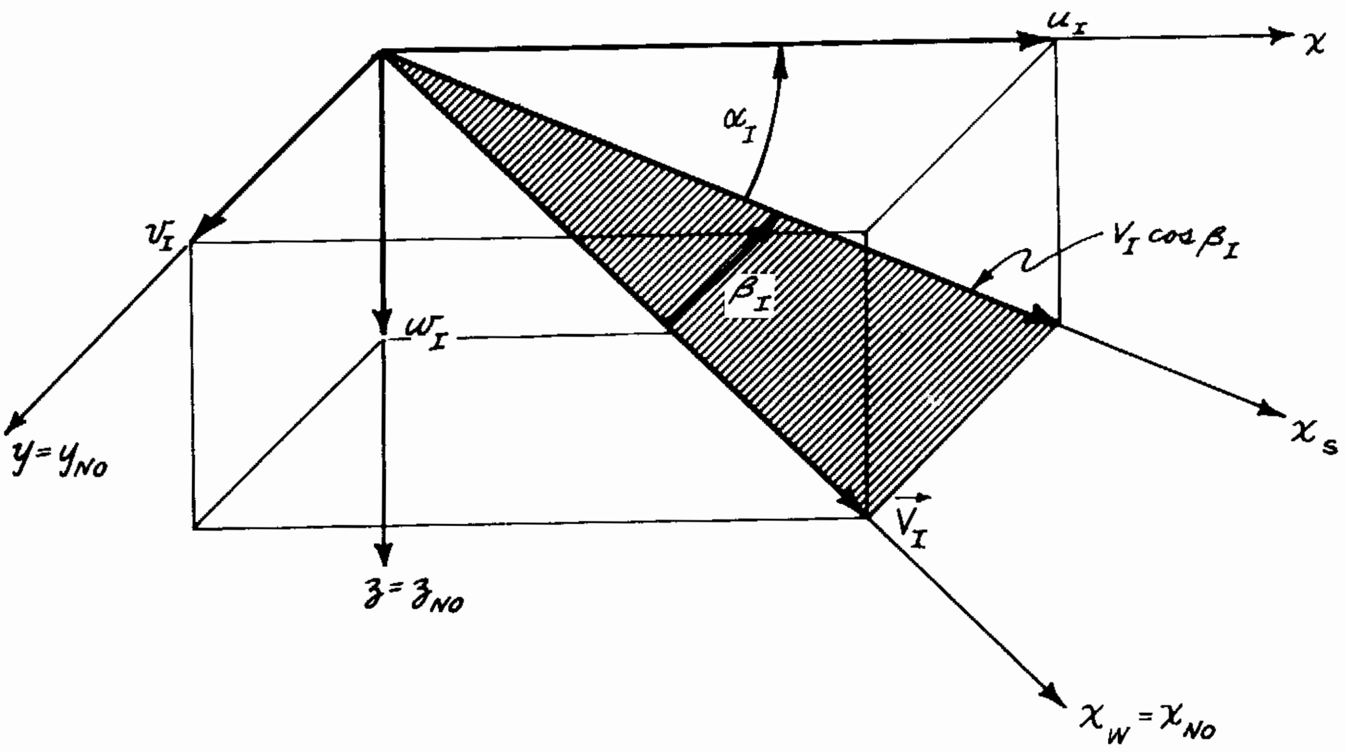
θ	Pitch angle, deg
ρ	Air density, slugs/ft^3
τ_R	Roll mode time constant, sec
τ_s	Spiral mode time constant, sec
ϕ	Bank angle, deg
$\lvert\phi/\beta\rvert_d$	At any instant, the ratio of amplitudes of the bank-angle and sideslip-angle envelopes in the Dutch roll mode
ψ	Yaw angle, deg
ψ_β	Phase angle of the Dutch roll oscillation in sideslip
ω_d	Undamped natural frequency of the Dutch roll mode, rad/sec
ω_{ph}	Undamped natural frequency of the phugoid mode, rad/sec
$\omega_{n_{sp}}$	Undamped natural frequency of the short period mode, rad/sec
ω_ϕ	Undamped natural frequency of numerator quadratic in bank angle to aileron input transfer function, rad/sec

Subscripts	
aero	aerodynamic
c	command
c.g.	center of gravity
d	Dutch roll
g	gust
I	inertial
m	model
p	pilot's location
ph	phugoid
SP	short period
t	trim
TCG	at the TIFS center of gravity

Superscripts	
L	left
R	right



AXES AND SIGN CONVENTIONS FOR TIFS



THE RELATION BETWEEN BODY AXES AND THE NONORTHOGONAL AXES

SECTION I

INTRODUCTION

An in-flight research program on the handling qualities of large, high-speed (Class III) airplanes in the landing approach has been conducted utilizing the TIFS airplane to demonstrate its capability for obtaining meaningful handling qualities data and, in addition, to provide information relevant to the application of MIL-F-8785B(ASG) to those airplanes. This work is, in effect, the culmination of the TIFS development program. The TIFS airplane, with its unique model-following capabilities, provides a research tool wherein the motions of the pilot station are duplicated, and the visual cues are experienced in the actual performance of the task under investigation. Thus, in the landing approach maneuver utilized in this program, the simulation limitation is essentially dependent only upon the description of the equations of motion and stability parameters of the model to be evaluated. For this program, the model information was provided by the North American Rockwell Corporation and the B-1 SPO to assure that the results can be applicable to the B-1 development program.

The recently revised military specification MIL-F-8785B(ASG), Reference 1, divides requirements for a given Class of airplane and Flight Phase into Levels associated with the ability to perform the given task with a desired degree of success. If the specified Level of handling qualities is not exhibited by an unaugmented airplane in the performance of a task, then either the design must be revised or a reliable augmentation system must be used or some combination of both is required in order to achieve that Level. For the designer to properly evaluate the possible alternatives, it is of fundamental importance that he be able to determine accurately the handling qualities of the unaugmented airplane. Hence, it is highly important that trends in pilot rating with variations in stability and control derivatives over which the designer has reasonable control, or with those derivatives which are normally difficult to either estimate or determine from test data, be established relatively early in the design phase to provide the data required for effective tradeoff studies. Although this information may, to a certain extent, be provided by ground simulation studies, the use of the TIFS airplane provides data acquired in the actual flight environment.

This report describes the results of Phase I of the initial research program to be performed on TIFS. The program was divided into two research phases: Phase I was directed at the lateral-directional handling qualities of an unaugmented Class III aircraft in the landing approach Flight Phase, while in Phase II, the longitudinal handling qualities in the same Flight Phase were investigated. A single set of longitudinal stability and control derivatives, representative of Class III airplanes, was employed in the Phase I study reported herein. Similarly, in the Phase II program, (AFFDL-TR-71-164, Volume II separately reported) constant lateral-directional characteristics were employed. The report, like the research program phases, is divided into two parts as well as into various sections. Section II describes the fundamental parameters varied as well as the effects of these variations on modal parameters. Section III describes the experiment, the evaluation aids provided the pilot, and, in addition, the TIFS airplane. A synopsis of the pilot comments and the results of the in-flight investigation are included in Section IV. Section V contains a summary of the experimental results and conclusions. In addition, appendices are included to describe the equations of motion of the model, transient responses, and model-following capability of the TIFS as well as edited versions of the complete pilot comments.

SECTION II

TECHNICAL DISCUSSION

2.1 PURPOSE OF THE EXPERIMENT

The in-flight simulation performed served two purposes: first, to utilize the TIFS variable stability airplane in a research task for the first time since the development of the airplane; secondly, to investigate the flying qualities in the landing approach Flight Phase of Class III airplanes.

The development and description of the TIFS airplane and its model-following system are presented in several reports and papers (References 2 through 7). However, to develop this new and unique research airplane to its fullest potential requires the development of procedures and techniques to effectively and efficiently utilize the airplane. This can best be accomplished by the performance of specific research tasks. The techniques utilized in this research program are described in the following section of this report. Examples of model following for classic inputs and during the evaluation maneuvers are illustrated on Figures V-1 through V-9 in Appendix V of this report. These figures indicate the fidelity of model following achieved in this first research program with the TIFS airplane.

The in-flight research experiment performed in Phase I was an investigation in the landing approach Flight Phase of variations in lateral-directional stability and control derivatives representative of an unaugmented Class III airplane. The reasons for application of the TIFS airplane to this experiment are self-evident: (1) the ability of the model-following system to accurately simulate the motion at the pilot's station for large airplanes; (2) all motion cues, instrument and visual cues are accurately presented to the evaluation pilot for the particular maneuvers under investigation, by actually flying in the landing approach phase.

2.2 DESCRIPTION OF THE DERIVATIVES VARIED IN THE EXPERIMENT

There are several approaches to the design of a handling qualities research experiment. One approach is to design a generalized experiment, i.e., select the modal characteristics of the type of airplane under investigation and then vary significant functions. This approach was used for example in Reference 8. Reference 9 indicates the direct relationships between stability derivatives and modal parameters; thus it is possible to also introduce realistic constraints on stability and control derivatives when a generalized modal parameter variation is used to design a handling qualities experiment. A second approach is to describe the stability and control derivatives of a particular airplane under investigation, and to perform perturbations in these derivatives in an attempt to evaluate the effects of these variations on flying qualities. Either realistic physical constraints and/or derivative variations encompassing the uncertainty of the airplane designer should be used to limit the perturbations. This second approach was used in this experiment. The derivatives used and the variations indicated below are based upon discussions with representatives of the Los Angeles Division of the North American Rockwell Corporation.

Baseline Configuration (Lateral-Directional) Body Axis * CG=25%MAC

W = 152,300 lb

b = 136.7 ft

S = 1946 ft^2

$\bar{c}$ = 15.3 ft

I_{xx} = 1,105,000 slug-ft^2

I_{yy} = 3,490,000 slug-ft^2

I_{zz} = 4,480,000 slug-ft^2

I_{xz} = -15,000 slug-ft^2

C_{l_β} = -.0172/rad

C_{n_β} = +.1415/rad

C_{y_β} = -.6933/rad

$C_{l_{\delta_r}}$ = +.0126/rad

$C_{n_{\delta_r}}$ = -.0573/rad

$C_{y_{\delta_r}}$ = +.1490/rad

$C_{l_{\delta_a}}$ = -.0733/rad

$C_{n_{\delta_a}}$ = -.0115/rad

$C_{y_{\delta_a}}$ = +.0264/rad

X_T = 0

Z_T = 0

δ_a = ± 100 deg

δ_r = ± 25 deg

δ_e = ± 25 deg

C_{l_p} = -.62/rad

C_{n_p} = -.105/rad

C_{y_p} = +.07/rad

C_{l_r} = +.21/rad

C_{n_r} = -.148/rad

C_{y_r} = +.313/rad

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* see figures in List of Symbols for axes and sign conventions

The following example illustrates the use of Table I. Configuration P-14 is indicated as BL with C_{l_β} = +5 (BL) and $C_{n_{\delta_a}}$ = +3 (BL); thus C_{l_β} = 5 (-.0172/rad) = -.086/rad, $C_{n_{\delta_a}}$ = +3 (-.0115/rad) = -.0345/rad, while all other derivatives are at the baseline values previously indicated.

Table I

CONFIGURATIONS EVALUATED IN PHASE I RESEARCH PROGRAM

CONFIGURATION	DESCRIPTION
P-1	Baseline Configuration (BL)
P-2	BL, with $C_{n_{\delta_a}}$ = +3 (BL)
P-3	BL, with $C_{n_{\delta_a}}$ = -3 (BL)
P-4	BL, with $C_{n_{\delta_a}}$ = +6 (BL)
P-6	BL, with C_{l_β} = +5 (BL)
P-7	BL, with C_{l_β} = +10 (BL)
P-8	BL, with C_{n_p} = +3 (BL)
P-9	BL, with C_{n_p} = -3 (BL)
P-12	BL, with C_{l_β} = +5 (BL) and C_{n_p} = +3 (BL)
P-13	BL, with C_{l_β} = +5 (BL) and C_{n_p} = -3 (BL)
P-14	BL, with C_{l_β} = +5 (BL) and $C_{n_{\delta_a}}$ = +3 (BL)
P-16	BL, with C_{l_β} = +5 (BL) and $C_{n_{\delta_a}}$ = +6 (BL)
S-1	BL, with C_{l_r} = +2(BL)
S-2	BL, with C_{l_r} = +3 (BL)
S-3	BL, with C_{l_r} = +2 (BL) and $C_{n_{\delta_a}}$ = +3 (BL)
S-5	BL, with C_{l_r} = +2 (BL) and $C_{n_{\delta_a}}$ = +6 (BL)
S-7	BL, with C_{l_r} = +2 (BL) and C_{l_β} = +5 (BL) and $C_{n_{\delta_a}}$ = +3 (BL)

Examination of the previous table indicates that the following groups of data may be examined for specific trends in pilot ratings with particular stability and control derivatives.

A) Variations in $C_{n_{\delta a}}$

1. P-1, P-2, P-3, P-4
2. P-6, P-14, P-16
3. S-1, S-3, S-5

B) Variations in C_{l_β}

1. P-1, P-6, P-7
2. P-2, P-14
3. P-4, P-16
4. P-8, P-12
5. P-9, P-13
6. S-3, S-7

C) Variations in C_{n_p}

1. P-1, P-8, P-9
2. P-6, P-12, P-13

D) Variations in C_{l_r}

1. P-1, S-1, S-2
2. P-2, S-3
3. P-4, S-5

(This information and supplementary data are also presented on page 49 as a convenience to the reader.)

These groups will be examined further in this section and in Section IV of this report. Transfer function numerators, characteristic values, and responses of the configurations to step aileron and rudder commands are presented in Appendix IV.

2.3 LONGITUDINAL STABILITY AND CONTROL DERIVATIVES

For the Phase I research program, the longitudinal stability and control derivatives were held constant for all configurations evaluated, at the following values (with the model c.g. at .25 $\bar{c}$ using stability axis).

$C_L|_{\alpha=0} = 1.47$ $\qquad$ $C_m|_{\alpha=0} = -.31$

$C_{L_\alpha} = 7.449/\text{radian}$ $\qquad$ $C_{m_\alpha} = -.722/\text{radian}$

$C_{L_{\delta_e}} = .8309/\text{radian}$ $\qquad$ $C_{m_{\delta_e}} = -2.865/\text{radian}$

$C_{L_q} = 17.9/\text{radian}$ $\qquad$ $C_{m_q} = -29.2/\text{radian}$

$C_{L_{\dot{\alpha}}} = 1.3/\text{radian}$ $\qquad$ $C_{m_{\dot{\alpha}}} = -10.8/\text{radian}$

Longitudinal Model Trim Data ($\gamma_t = 0^\circ$)
at Sea Level for a Standard Day

V_t ~ knots	α_t ~ deg	δ_{e_t} ~ deg
110	4.19	-7.26
120	1.77	-6.65
130	-.10	-6.17
135	-.90	-5.95
140	-1.59	-5.80
150	-2.80	-5.50
160	-3.78	-5.25

Drag was mechanized as $C_D = C_{D_0} + KC_L^2$. The following values were used for the Phase I research program: $C_{D_0} = .12$, $K = .0384$. K was evaluated as $1/\pi ARe$ where the aspect ratio is 8.93 and the efficiency factor (e) was assumed at .93.

The longitudinal modal parameters for this configuration computed at the trim airspeed of 135 knots are as follows:

$\omega_{n_{sp}}$ = .899 rad/sec $\qquad$ ω_{ph} = .137 rad/sec

ζ_{sp} = .857 $\qquad$ ζ_{ph} = .09

n/α = 5.61 g/rad $\qquad$ $\frac{1}{T_{\theta_1}}$ = .06472, $\frac{1}{T_{\theta_2}}$ = .7932

Comparison of these longitudinal modal parameters with MIL-F-8785B(ASG) requirements indicates the following Levels of compliance for a Class III airplane in Flight Phase Category C.

Requirement	Subject	Level of Compliance
3.2.1.2	Phugoid stability	1
3.2.2.1.1	Short period frequency and acceleration sensitivity	2
3.2.2.1.2	Short period damping	1

2.4 FEEL SYSTEM AND ACTUATOR DYNAMICS

The feel system dynamics for aileron, rudder and elevator were selected at values considered typical for this class of airplane and were not varied during the experiment. All feel system controls were assumed as second order systems with a damping ratio of .85 and a natural frequency of 15 radians/second. In addition, to simulate the effect of actuator dynamics, the model included a first order actuator with a time constant of .15 seconds between the command signals from the feel system output and the input to the model control surfaces. Throttle and thrust dynamics were mechanized as a second order system with a damping ratio of .8 and natural frequency of 1.85 radians/second.

2.5 TYPE OF COCKPIT CONTROLLER

The TIFS airplane as utilized in the Phase I experiment had a wheel controller in the evaluation cockpit. Reference 8, which reported an examination of Class II airplanes in the landing approach task, clearly demonstrated that there was no significant difference in pilot opinion dependent upon the type of controller, wheel or stick, used when the pilot selected optimum sensitivity. Thus, although it was not demonstrated in the Phase I program it may be assumed, based on the results of the experiment referenced above, that the trends obtained in pilot rating would not be significantly different if the Phase I program had been performed with a stick controller rather than a wheel.

2.6 EXAMINATION OF THE LATERAL-DIRECTIONAL MODAL CHARACTERISTICS OF THE CONFIGURATIONS EVALUATED

The lateral-directional stability derivatives have been previously defined in paragraph 2.2 of this section. The purpose of this paragraph is to examine the effects of the variations of these stability and control derivatives in terms of modal parameters for the stability derivatives and the effects of the control derivatives in terms of numerator characteristics of selected lateral-directional transfer functions. The data to be presented is based upon the results of a linearized, three-degree-of-freedom equations-of-motion digital program. The trim condition was established at 135 knots with the aircraft stabilized in a three degree glide slope. Although it is customary to present a root locus diagram to describe the effects of changes in the characteristic equation (pole locations) as a stability derivative is varied, it was decided to present the effects of these variations separately on each mode of airplane response in order to show direct comparison to the requirements of MIL-F-8785B(ASG),Reference 1.

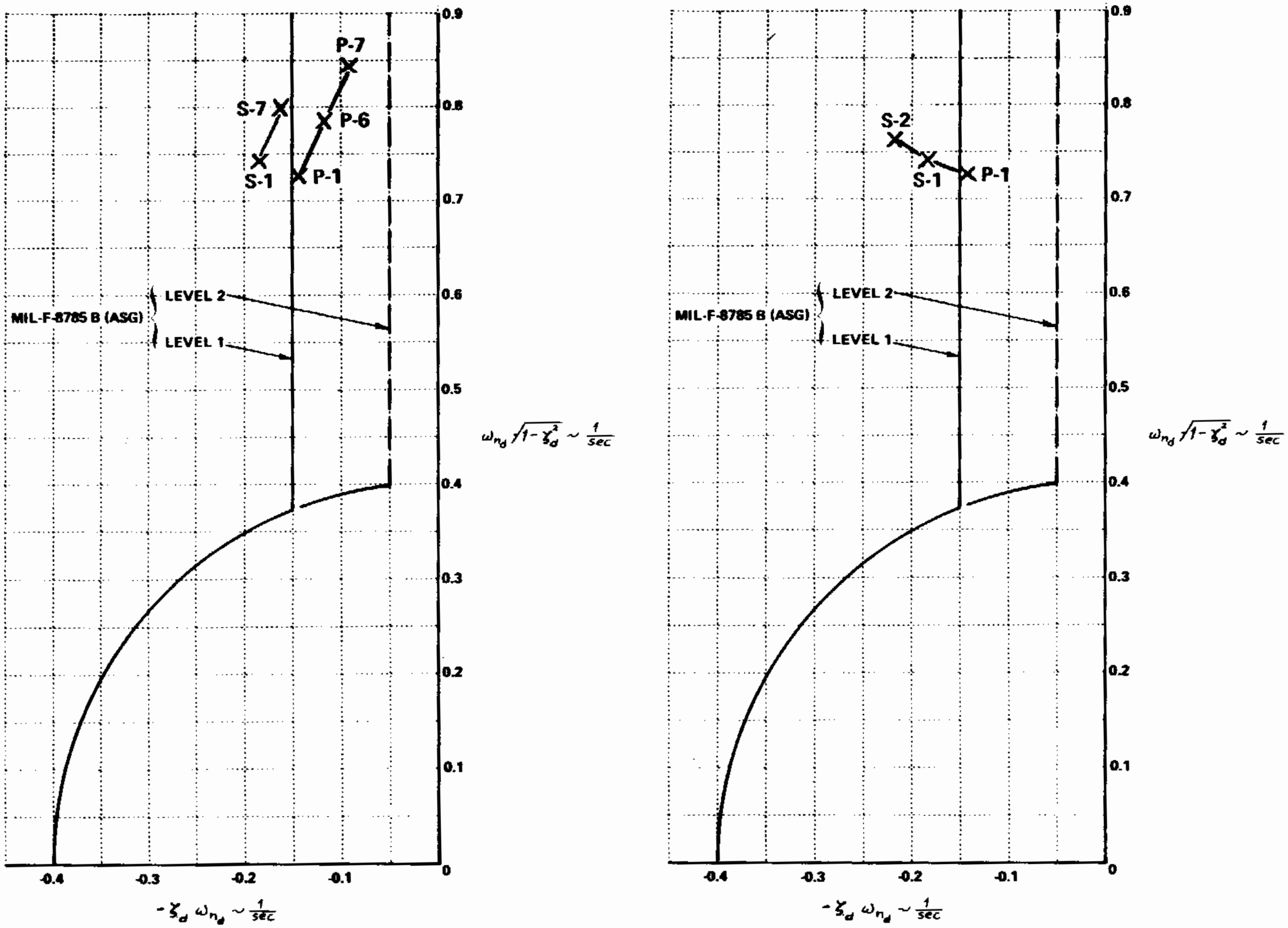
2.6.1 Dutch Roll Mode Poles

Figure 1 indicates the location of the Dutch roll roots for the various combinations of stability derivatives evaluated. For the configurations under evaluation in this experiment, the following summarizes the effects on the Dutch roll mode pole:

1. Increasing C_{ℓ_β} in a negative sense (P-1 to P-6 to P-7) and (S-1 to S-7) increases the Dutch roll frequency and decreases the damping ratio (Figure 1a).

2. Increasing C_{ℓ_r} in a positive sense (P-1 to S-1 to S-2) increases the Dutch roll frequency and increases the damping ratio (Figure 1b).

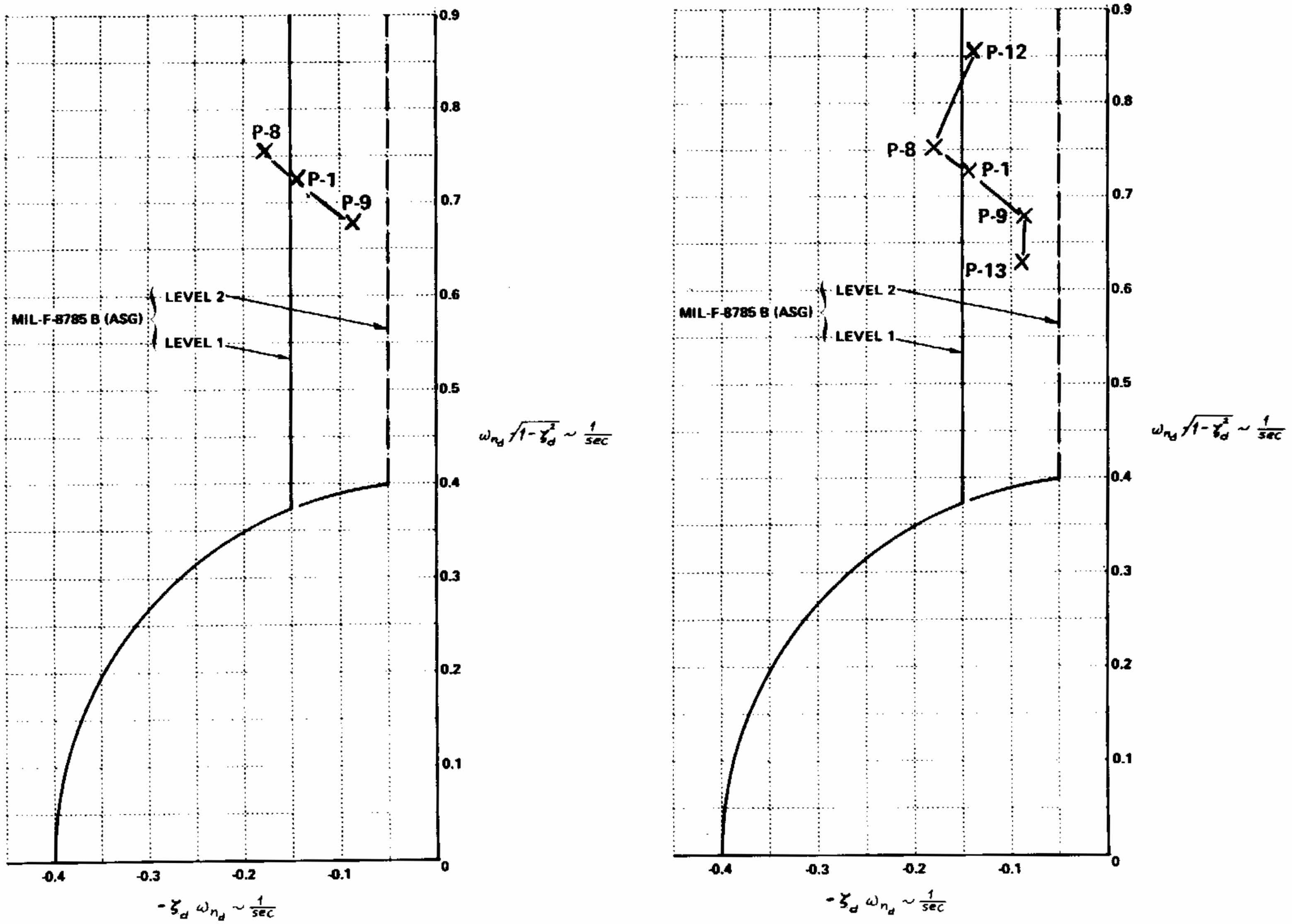
3. Increasing C_{n_p} in a negative sense (P-1 to P-8) increases Dutch roll frequency and damping ratio while increasing C_{n_p} in a positive sense (P-1 to P-9) decreases both the Dutch roll frequency and damping ratio (Figure 1c).



a) CHANGE IN C_{ℓ_β}

b) CHANGE IN C_{ℓ_r}

FIGURE 1 EFFECT OF STABILITY DERIVATIVE VARIATIONS ON DUTCH ROLL MODE POLE



c) CHANGE IN C_{n_p}

d) CHANGE IN C_{n_p}, C_{l_β}

FIGURE 1 CONTINUED

4. Increasing C_{n_p} and C_{l_β} in a negative sense (P-1 to P-8 to P-12) increases Dutch roll frequency and reduces the damping ratio, while increasing C_{n_p} in a positive sense (P-1 to P-9) and then increasing C_{l_β} in a negative sense (P-9 to P-13) reduces Dutch roll frequency and increases damping ratio (Figure 1d).

Figures 1a - 1d also indicate the location of the Dutch roll mode in comparison to an s-plane presentation of the requirements of MIL-F-8785B(ASG), Reference 1. This type of plot is useful to demonstrate the change of the Dutch roll poles (root locus) and their relationship to specification requirements as a stability derivative is varied.

2.6.2 Roll Mode Time Constant

The following table describes the effect of the variations on the roll mode time constant. In all cases the value indicated meets the Level 1 requirement of MIL-F-8785B(ASG), Reference 1.

CONFIGURATION	τ_R ~ SECONDS	PARAMETER VARIED
P-1	.373	C_{l_β}
P-6	.368	
P-7	.363	
P-1	.373	C_{l_r}
S-1	.377	
S-2	.382	
P-1	.373	C_{n_p}
P-8	.383	
P-9	.354	
P-1	.373	C_{n_p} , C_{l_β}
P-8	.383	
P-12	.374	
P-1	.373	C_{n_p}, C_{l_β}
P-9	.354	
P-13	.357	
S-1	.377	C_{l_β}
S-7	.372	

2.6.3 Spiral Mode Stability (Time to Double Amplitude)

Figure 2 summarizes the effect of the stability derivative variations of the spiral mode in terms of time to double amplitude. The data presented is again based on the result of solving for the roots of the characteristic equation obtained from the linearized three-degree-of-freedom equations-of-motion digital program. The requirements of MIL-F-8785B(ASG), Reference 1 are also presented on the same figure. The specification requirements include the effects of control system characteristics and trim changes with speed, since this is more representative

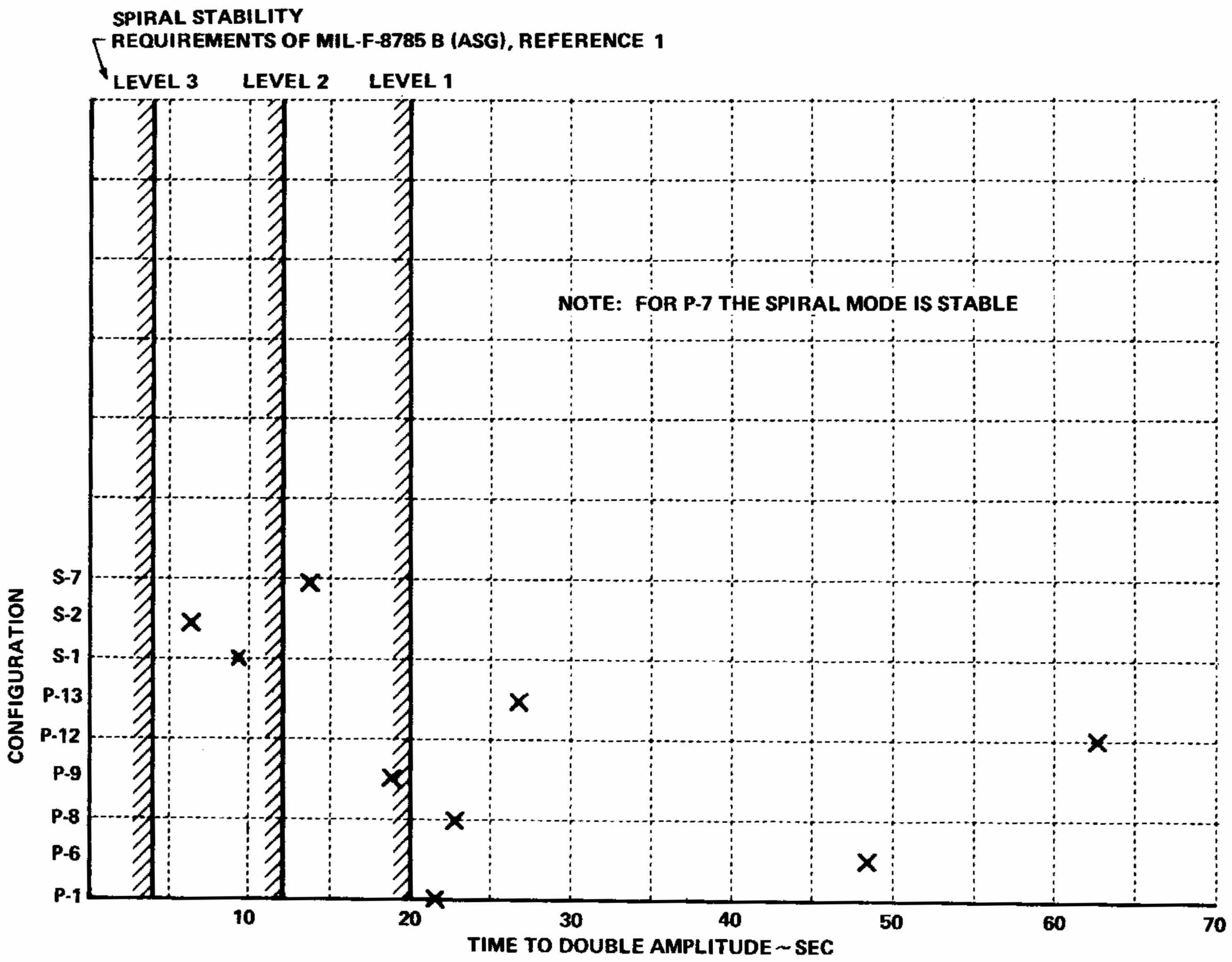


Figure 2 EFFECT OF STABILITY DERIVATIVE VARIATIONS ON SPIRAL MODE STABILITY

of the overall spiral stability as seen by the pilot than only the position of the characteristic root. The following summarizes the effect of stability derivative variations on spiral stability:

1. Increasing C_{ℓ_β} in a negative sense (P-1 to P-6 to P-7) and (S-1 to S-7) increases spiral stability.

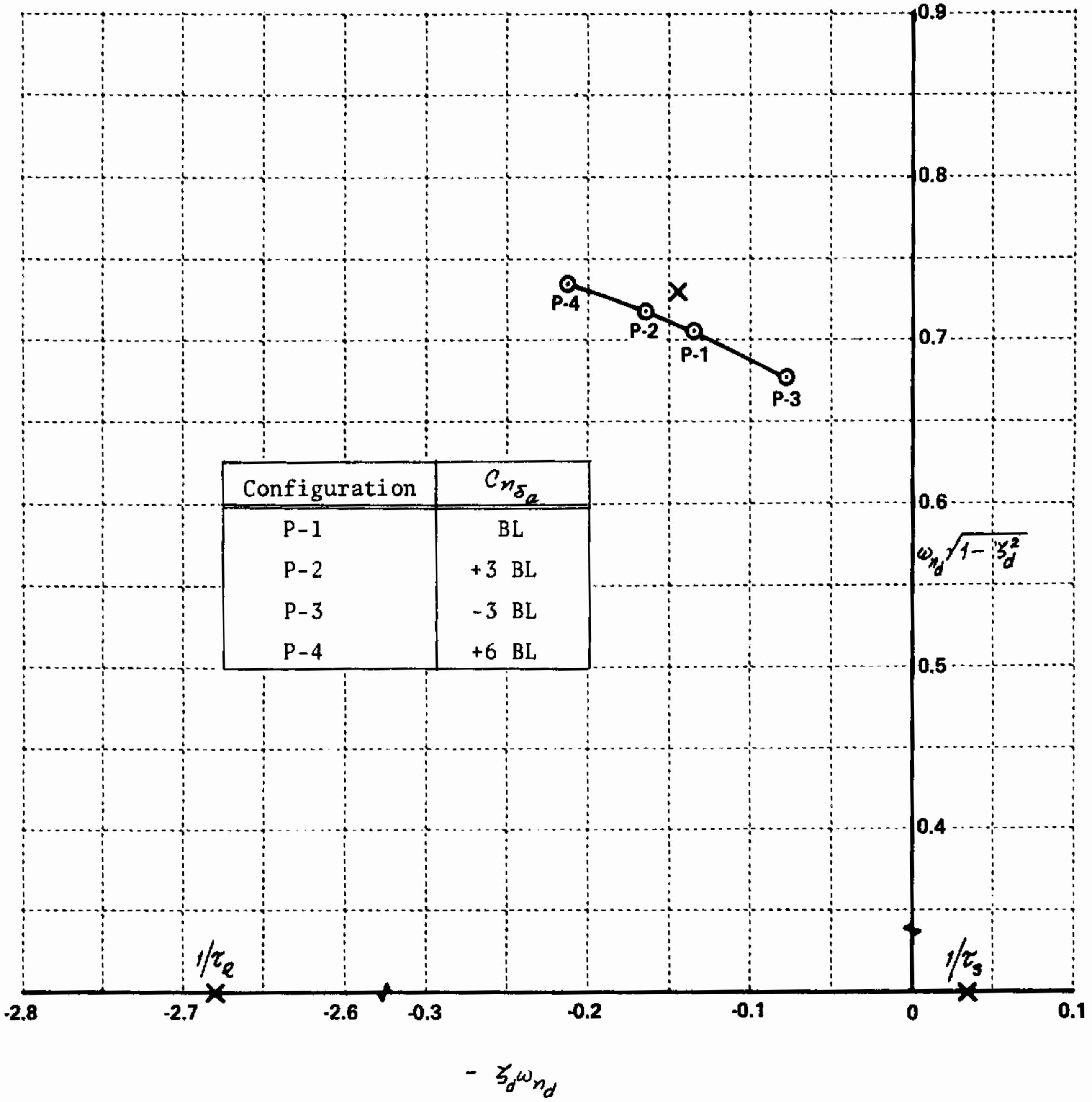
2. Increasing C_{ℓ_r} in a positive sense (P-1 to S-1 to S-2) decreases spiral stability.

3. Increasing C_{n_p} in a negative sense (P-1 to P-8) increases spiral stability, while increasing C_{n_p} in a positive sense (P-1 to P-9) decreases spiral stability.

4. A simultaneous change of C_{n_p} in a negative sense and C_{ℓ_β} in a negative sense (P-1 to P-12) results in an increase in spiral stability. Similarly, a simultaneous change of C_{n_p} in a positive sense and C_{ℓ_β} in a negative sense (P-1 to P-13) also results in an increase in spiral stability.

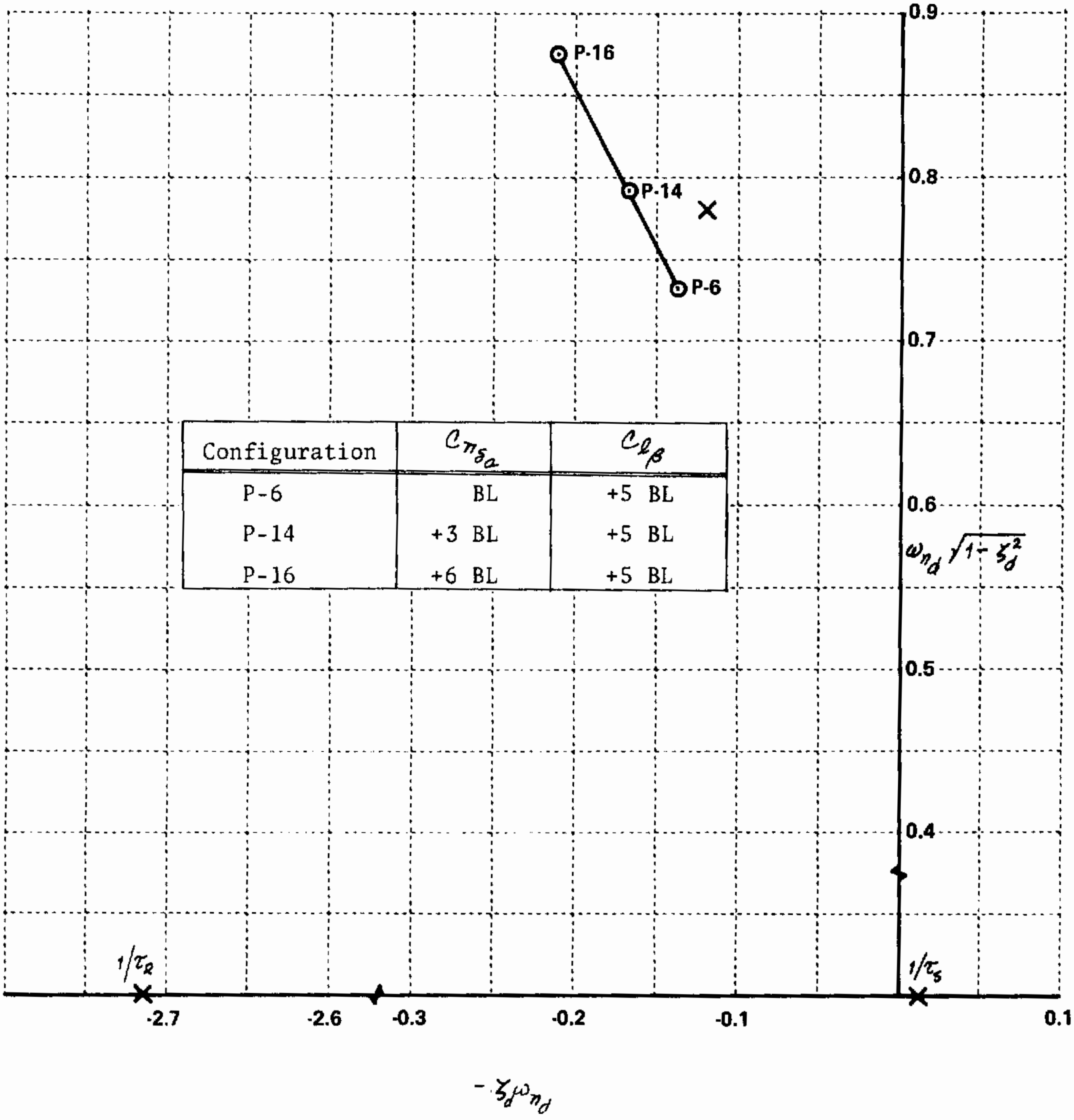
2.6.4 Effect of Changes in Yaw Due to Aileron ($C_{n_{\delta_a}}$) on the Zero Locations of the ϕ/δ_a Transfer Function Numerator

Figures 3 through 5 indicate the effects of change in the magnitude and sign of yaw due to aileron ($C_{n_{\delta_a}}$) on the location of the numerator zero of the ϕ/δ_a transfer function. Although yaw due to aileron affects the transfer functions of all state variables, etc., with respect to an



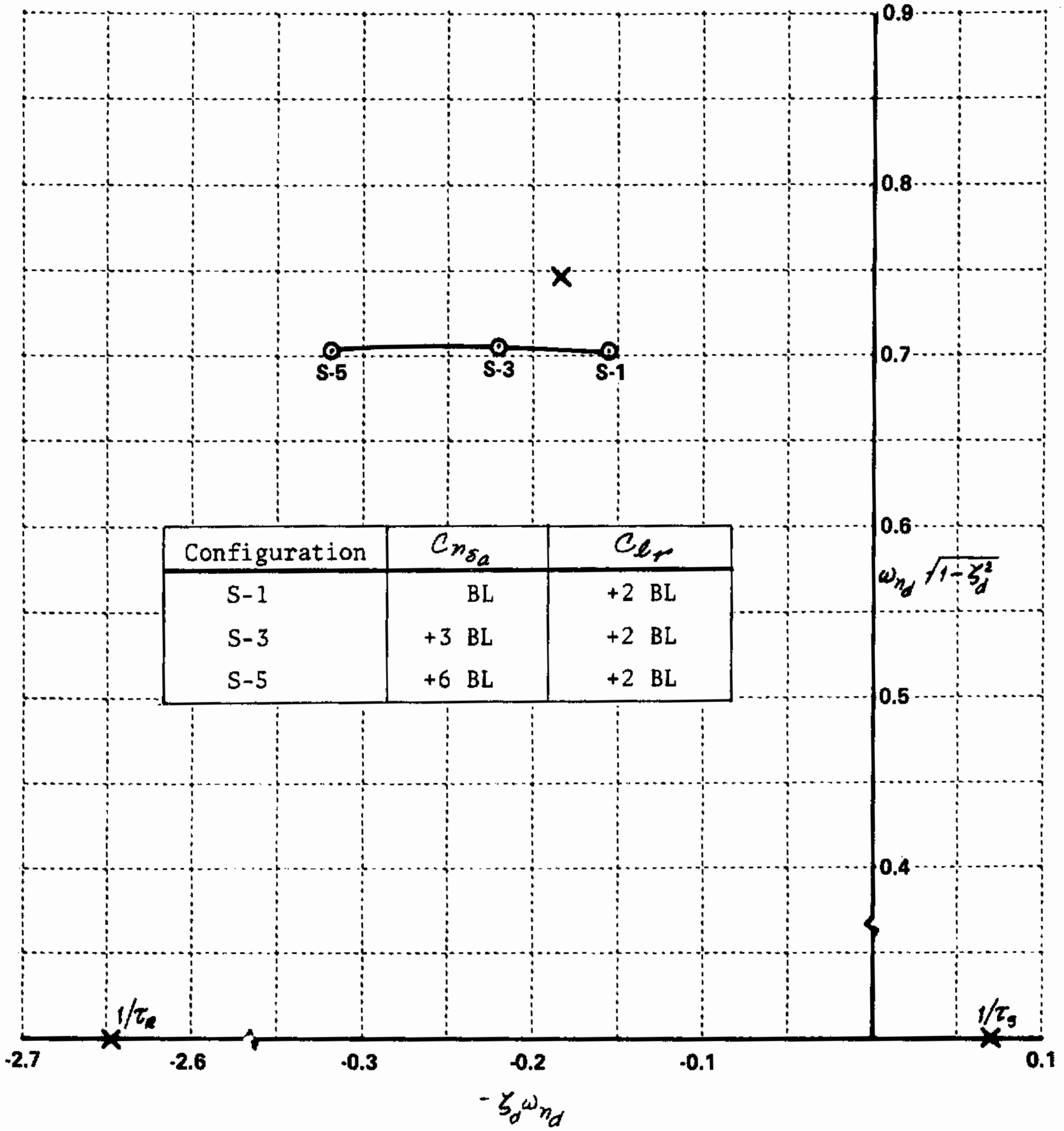
Configuration	$C_{n_{\delta_a}}$
P-1	BL
P-2	+3 BL
P-3	-3 BL
P-4	+6 BL

FIGURE 3 EFFECT OF VARIATIONS IN $C_{n_{\delta_a}}$ ON THE ϕ/δ_a NUMERATOR ZEROS FOR THE BASELINE CONFIGURATION



Configuration	$C_{n_{\delta_a}}$	C_{l_β}
P-6	BL	+5 BL
P-14	+3 BL	+5 BL
P-16	+6 BL	+5 BL

FIGURE 4 EFFECT OF VARIATIONS IN $C_{n_{\delta_a}}$ ON THE ϕ/δ_a NUMERATOR ZEROS FOR THE BASELINE CONFIGURATION WITH INCREASED DIHEDRAL



Configuration	$C_{n_{\delta_a}}$	C_{l_r}
S-1	BL	+2 BL
S-3	+3 BL	+2 BL
S-5	+6 BL	+2 BL

FIGURE 5 EFFECT OF VARIATIONS IN $C_{n_{\delta_a}}$ ON THE ϕ/δ_a NUMERATOR ZERO FOR THE BASELINE CONFIGURATION WITH INCREASED C_{l_r}

aileron input, it is perhaps easiest to visualize these effects most directly in the bank angle transfer function. As indicated in both References 10 & 11, the location of the ϕ/δ_a numerator zero with respect to the Dutch roll pole has a significant effect on the coupling between bank angle response and sideslip for an aileron input. A comparison of the trajectory on the s-plane of the ϕ/δ_a numerator zero illustrates the effects of C_{l_β} and C_{l_r} on the zero location. It is apparent that for the trajectories shown the minimum distance between the ϕ/δ_a numerator zero and the Dutch roll pole is for values of $C_{n_{\delta_a}}$ between the baseline value and $C_{n_{\delta_a}} = +3$ (BL). Based on the discussions of References 10 and 11, this region should be indicative of minimum p_{osc}/p_{AV} and $\Delta\beta_{max}/k$. In order to examine the effect of zero location, a linear three-degree-of-freedom equations-of-motion program was utilized to determine p_{osc}/p_{AV} and $\Delta\beta_{max}/k$ for small aileron step commands. The results of this analytical investigation are presented on Figures 6 through 8.

Figure 6 illustrates the location of various configurations in the p_{osc}/p_{AV}, ψ_β plane of requirements of MIL-F-8785B(ASG), Reference 1. Unfortunately, because of the effect of the spiral mode, and the relatively long period Dutch roll mode (see figures in Appendix IV) it was only possible to analytically determine p_{osc}/p_{AV} for the eight configurations shown on Figure 7. This does point out a possibly significant shortcoming in the military specification requirement, since the measurement of peaks to determine p_{osc}/p_{AV} is either impossible or impractical. However, the following observation can be made on the effect of the ϕ/δ_a numerator zero location for configurations P-6, P-14 and P-16. As previously indicated, the minimum

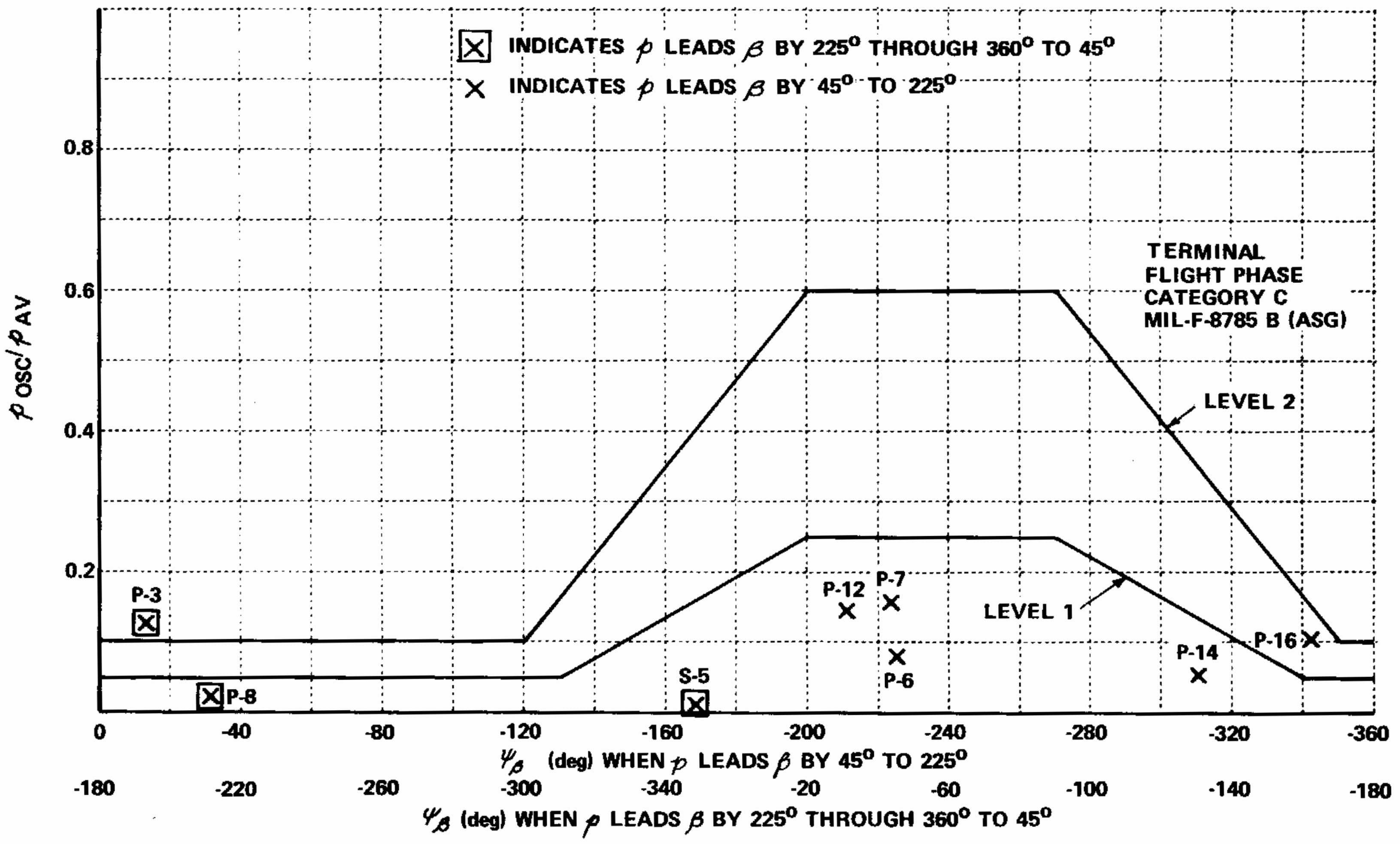


FIGURE 6 LOCATION OF THE CONFIGURATIONS IN THE ρ_{osc}/ρ_{AV} REQUIREMENT PLANE

value of p_{osc}/p_{AV} occurs as the baseline configuration yaw due to aileron is increased in the proverse direction. In addition, the effect of increasing the effective dihedral (P-6, P-7) which in turn increased $|\phi/\beta|_d$ is a significant increase in p_{osc}/p_{AV}. Furthermore, a comparison of the locations of Configurations P-16 and S-5 indicates that for the configurations under investigation increasing C_{ℓ_r} will reduce p_{osc}/p_{AV}. This result is related to several factors, among them that the larger value of C_{ℓ_r} increases the damping of both numerator and denominator of the ϕ/δ_a transfer function and, in addition, reduces the value of ω_ϕ/ω_d for the same value of $C_{n_{\delta_a}}$. For several of the configurations evaluated, p leads β by 225° through 360° to 45° during a controls-fixed Dutch roll oscillation, which is indicative of effective negative dihedral as explained in Reference 10. The following table indicates the value of $\measuredangle p/\beta$ in the Dutch roll mode:

Table II

EFFECT OF STABILITY DERIVATIVE VARIATIONS ON EFFECTIVE DIHEDRAL

CONF.	Effective Dihedral	$\measuredangle \phi/\beta_d$	IDENTIFICATION
P-1	Neg	229°	BL
P-2	Neg	229°	BL, with $C_{n_{\delta_a}}$ = +3 (BL)
P-3	Neg	229°	BL, with $C_{n_{\delta_a}}$ = -3 (BL)
P-4	Neg	229°	BL, with $C_{n_{\delta_a}}$ = +6 (BL)
P-6	Pos	187°	BL, with C_{l_β} = +5 (BL)
P-7	Pos	174°	BL, with C_{l_β} = +10 (BL)
P-8	Neg	232°	BL, with C_{n_p} = +3 (BL)
P-9	Neg or Pos	225°	BL, with C_{n_p} = -3 (BL)
P-12	Pos	188°	BL, with C_{l_β} = +5 (BL), C_{n_p} = +3 (BL)
P-13	Pos	184°	BL, with C_{l_β} = +5 (BL), C_{n_p} = -3 (BL)
P-14	Pos	187°	BL, with C_{l_β} = +5 (BL), $C_{n_{\delta_a}}$ = +3 (BL)
P-16	Pos	187°	BL, with C_{l_β} = +5 (BL), $C_{n_{\delta_a}}$ = +6 (BL)
S-1	Neg	243°	BL, with C_{l_r} = +2 (BL)
S-2	Neg	248°	BL, with C_{l_r} = +3 (BL)
S-3	Neg	243°	BL, with C_{l_r} = +2 (BL), $C_{n_{\delta_a}}$ = +3 (BL)
S-5	Neg	243°	BL, with C_{l_r} = +2 (BL), $C_{n_{\delta_a}}$ = +6 (BL)
S-7	Pos	208°	BL, with C_{l_r} = +2 (BL), C_{l_β} = +5 (BL), $C_{n_{\delta_a}}$ = +3 (BL)

Figures 7 and 8 illustrate the location of the various configurations in the $\Delta\beta_{max}/k$, ψ_β plane of requirements of MIL-F-8785B. The values of $\Delta\beta_{max}/k$ for the configurations were analytically determined using a digital equations-of-motion program for small perturbations about the trim condition, and would be indicative of sideslip/heading problems with the configuration for abrupt but rather small aileron step commands. To account for actuator lags, the step aileron command was shaped by a first order time constant of .15 seconds in the digital program.

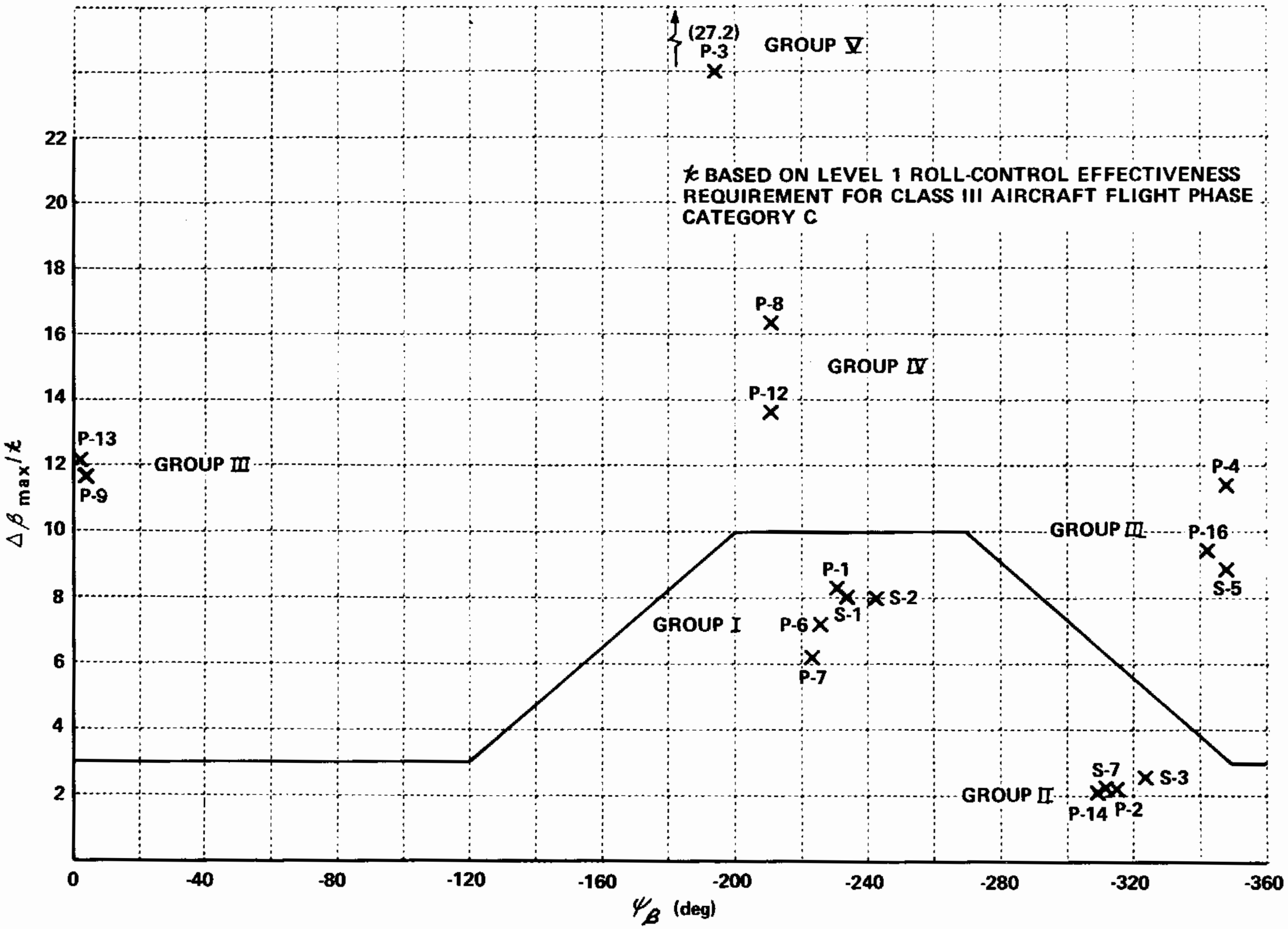


FIGURE 7 LOCATION OF THE CONFIGURATIONS IN THE $\Delta\beta_{max}/k$ REQUIREMENT PLANE (k BASED ON LEVEL 1 REQUIREMENTS)

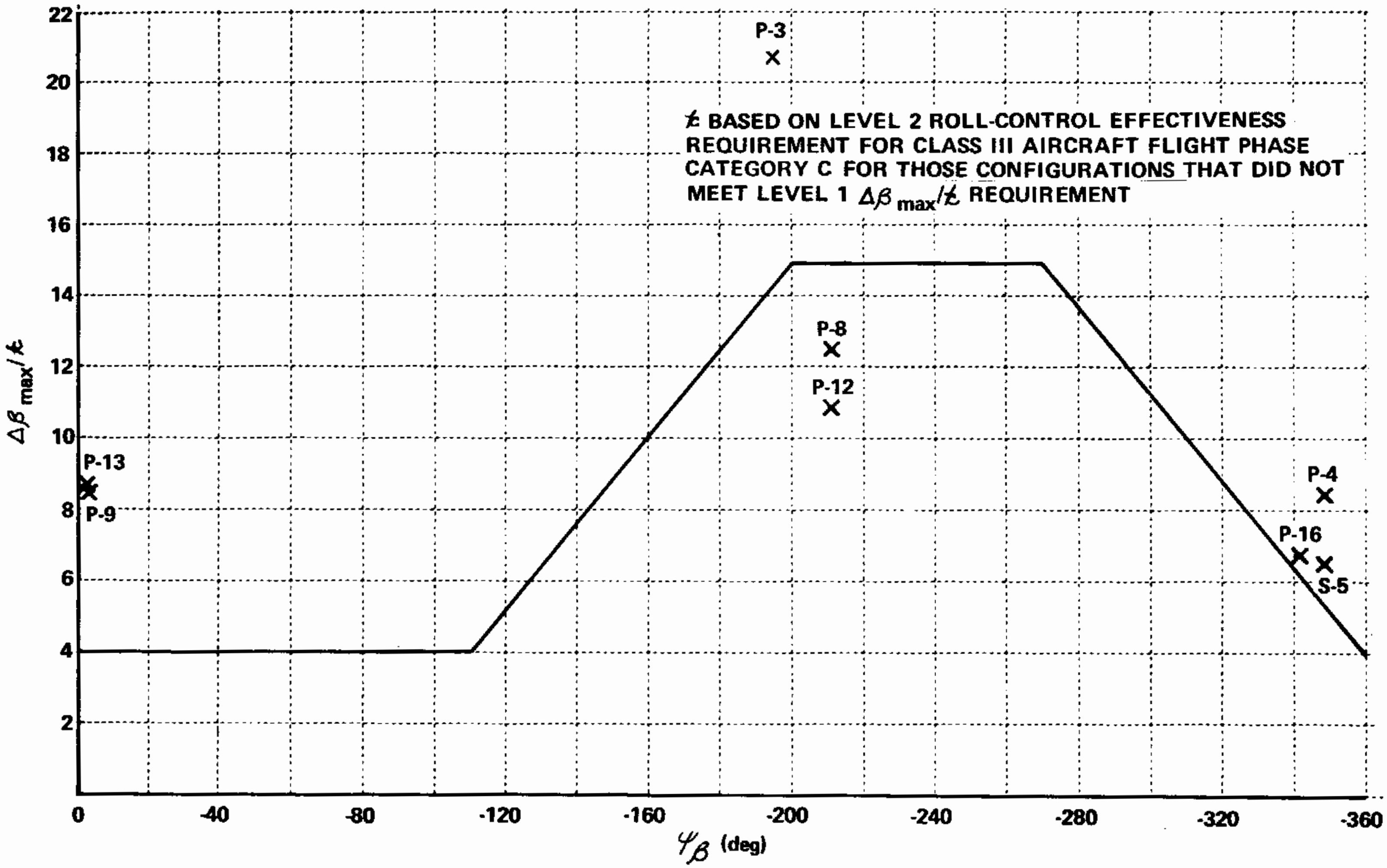


FIGURE 8 LOCATION OF THE CONFIGURATIONS IN THE $\Delta\beta_{max}/\not{k}$ REQUIREMENT PLANE (k BASED ON LEVEL 2 REQUIREMENTS)

The effect of variations in yaw due to aileron ($C_{n_{\delta_a}}$) can be examined by noting the trajectory of Configurations P-1, P-2, P-3, P-4; Configurations S-1, S-3, S-5, and Configurations P-6, P-14, P-16. In all cases an increase in the proverse yaw due to aileron from the baseline value to three times the baseline value resulted in a diminished value of $\Delta\beta_{max}/k$ while shifting ψ_β in the proverse sense. This ψ_β shift is indicative of a possible need to cross-control rudder inputs and aileron inputs (Reference 10). As discussed in Reference 11 sideslip excursions to aileron commands can be diminished as the value of $C_{n_{\delta_a}}$ is varied to essentially minimize the first order coefficient in the numerator of the β/δ_a transfer function. The proper value of $C_{n_{\delta_a}}$ for the given airplane stability derivatives could result in essentially a two-control airplane.

Examination of the locations of Configurations P-1, S-1, and S-2; Configurations P-2 and S-3 indicates no significant effect on sideslip excursions as C_{l_r} is increased for configurations with very small values of C_{l_β}. Comparison of Configurations P-4 and S-5 indicates that a reduction in $\Delta\beta_{max}/k$ for configurations with relatively large values of proverse yaw due to aileron can be achieved by increasing C_{l_r}.

Comparison of the location of Configurations P-1, P-6, P-7; Configurations P-4, P-16 and P-2, P-14 indicates that, for values of proverse yaw due to aileron which do not minimize $\Delta\beta/k$ for the given set of airplane stability derivatives, increasing the level of positive dihedral will reduce sideslip excursions to aileron inputs. No significant effect of C_{l_β} is noted when the value of $C_{n_{\delta_a}}$ used tends to minimize sideslip excursions by itself.

Further examination of Configurations P-8 and P-12 indicates that increasing C_{l_β} in a negative sense (increasing positive dihedral) can reduce sideslip excursions for aileron inputs for configurations with adverse C_{n_p} $(C_{n_p} < 0)$; however, no significant effect is noted for proverse C_{n_p} $(C_{n_p} > 0)$, Configurations P-9 and P-13*.

In general the use of the $\Delta\beta/k$ criteria of MIL-F-8785B(ASG) indicates that there should appear significant grouping of the evaluation configurations. Examination of pilot ratings and comments by these groupings as well as examination dependent upon the parameter varied are discussed in Section IV.

2.7 SUMMARY OF ANALYTICAL COMPARISON OF THE EVALUATION CONFIGURATIONS WITH SEVERAL MIL-F-8785B(ASG) REQUIREMENTS

The preceding discussions in this section indicate the location of the configurations evaluated in relationship to several of the lateral-directional requirements of MIL-F-8785B(ASG). Based on the results of an analytical investigation of the time history of airplane response to aileron commands the $\Delta\beta/k$ requirement indicates that the configurations tend to group together in specific locations on the plane of requirements. The

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*It must be remembered, that although increasing positive dihedral in terms of $C_{l_\beta} < 0$ may reduce sideslip excursions for an aileron command, the amount of $\varphi_{osc}/\varphi_{AV}$ will be significantly increased for the configurations to be evaluated, as previously noted.

following table summarizes the analytical comparison of the configurations with requirements of Reference 1, based on the Level of compliance with the applicable referenced specification requirements. (Reference 10 relates Levels to pilot ratings - Level 1 is pilot rating from 1 to 3.5, Level 2 is 3.5 to 6.5, and Level 3 is 6.5 to 9.5.)

Group By $\Delta\beta/k$	Configuration	Dutch Roll Level (3.3.1.1)	Roll Mode Level (3.3.1.2)	Spiral Mode Level Based on free root (3.3.1.3)	$\varphi_{osc}/\varphi_{AV}$ (3.3.2.2.1)	$\Delta\beta_{max}/k$ (3.3.2.4.1)
I	P-1	2	1	1	-	1
II	P-2	2	1	1	-	1
V	P-3	2	1	1	3*	3*
III	P-4	2	1	1	-	3*
I	P-6	2	1	1	1	1
I	P-7	2	1	1	1	1
IV	P-8	1	1	1	1	2
III	P-9	1	1	2	-	3*
IV	P-12	2	1	1	1	2
III	P-13	2	1	1	-	3*
II	P-14	2	1	1	1	1
III	P-16	2	1	1	2	3*
I	S-1	1	1	3	-	1
I	S-2	1	1	3	-	1
II	S-3	1	1	3	-	1
III	S-5	1	1	3	1	3*
II	S-7	1	1	2	-	1

It should be noted that an asterisk (*) appearing next to a Level value indicates a Level obtained by interpretation of paragraph 6.7.2 Level definitions of MIL-F-8785B(ASG). Specifically, when a configuration does not satisfy either Level 1 or Level 2 requirements, for the requirement under investigation, then the configuration is considered at best Level 3.

Section III

DESCRIPTION OF EXPERIMENT

3.1 EQUIPMENT

The flight evaluations of this program were flown in the Air Force Total In-Flight Simulator (TIFS) operated by CAL for the AFFDL, Air Force Systems Command (see Figure 9). The TIFS development, design and fabrication are described in Reference 4. The TIFS simulation cockpit, occupied by the evaluation pilot, is a completely separate cockpit mounted on the nose of the NC-131H to give the evaluation pilot as much of the simulated airplane environment as possible. The instrument panel used for this evaluation included the instruments developed under the PIFAX program (Pilot Factors Program sponsored by the FAA and performed under Air Force direction). The heart of this display is composed of two instruments: an Attitude Director Indicator (ADI) Model 4058-E and a Horizontal Situation Indicator (HSI) Model AQU-4 (see Figure 10). In the landing approach flight evaluation, the task included an ILS approach performed under simulated IFR conditions with the evaluation pilot wearing a hood. The ILS approaches were performed using flight director horizontal and vertical steering needles on the ADI driven by a Flight Director Computer Model CPU-27/A. In addition to these major instruments, other standard instruments included airspeed, rate of climb, altimeter, and engine instruments. Two other special instruments were available to the evaluation pilot in the left seat. A vertically moving needle indicating flight path angle, γ , was displayed on the left side of the ADI and horizontally moving needle indicating sideslip, β , was displayed below the ADI.

FIGURE 9 USAF/CAL TOTAL IN-FLIGHT SIMULATOR (TIFS)

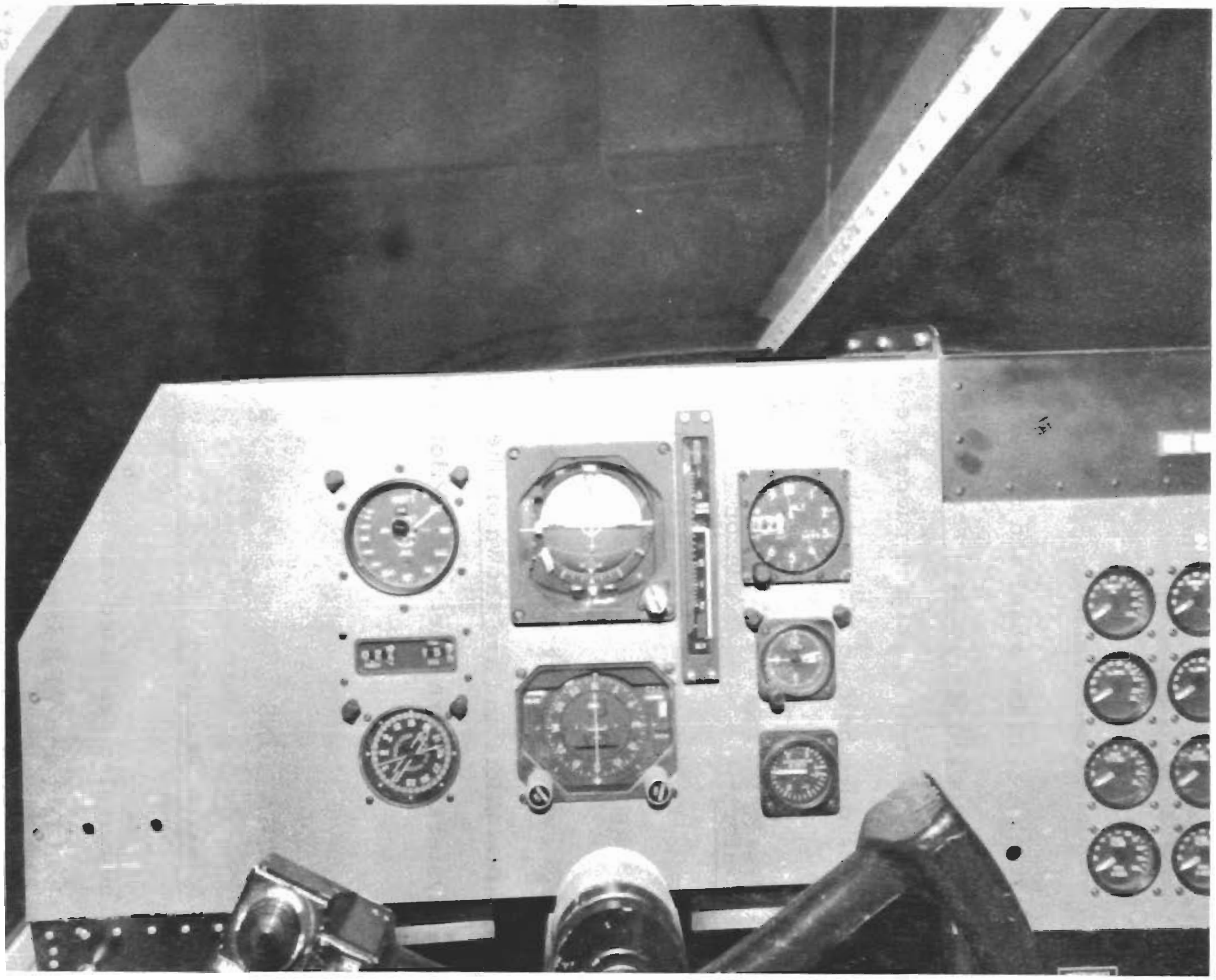


FIGURE 10 INSTRUMENT PANEL IN TIFS SIMULATION COCKPIT

The TIFS simulation cockpit is a two place side-by-side arrangement with control yoke and wheel and rudder pedals. Throttles are located between the two seats on a center console. The evaluation pilot occupied the left seat during the evaluation flight.

Control feel to the wheel and rudder pedals was provided by electrically controlled hydraulic feel servos which provide opposing forces proportional to the control wheel and rudder pedal deflection. The feel system dynamics were held constant at the values listed below:

Elevator	Aileron	Rudder
ω = 15 rad/sec	ω = 15 rad/sec	ω = 15 rad/sec
ζ = 85	ζ = .85	ζ = .85

Feel system spring rates and gearings were individually selected by the evaluation pilots and are shown on the following page. Breakout forces and hysteresis were selected by Pilot A and were not changed by the other pilots.

3.2 EVALUATIONS

3.2.1 Mission Definition

The mission evaluated was that of flying a Class III airplane in the terminal task of IFR and VFR landing approaches. Since it was planned not to touch down the TIFS while flying on the variable stability system (VSS), the approach was discontinued at some altitude below ILS minimums of 200 feet

			Pilot A	Pilot B	Pilot C
ELEVATOR					
Initial	F_{EW}/δ_{EW}	(lb/in.)	35.7		
	δ_e/δ_{EW}	(deg/in.)	2.88		
Final	F_{EW}/δ_{EW}	(lb/in.)	23.8	11.8	16.7
	δ_e/δ_{EW}	(deg/in.)	1.45	1.6	1.6
Breakout		(lb)	2.5	2.5	2.5
Hysteresis		(lb)	4.0	4.0	4.0
AILERON					
Initial	F_{AW}/δ_{AW}	(lb/deg)	1.0		
	δ_a/δ_{AW}	(deg/deg)	0.9		
Final	F_{AW}/δ_{AW}	(lb/deg)	0.3	0.15	0.24
	δ_a/δ_{AW}	(deg/deg)	0.6	1.4	1.4
Breakout		(lb)	2.5	2.5	2.5
Hysteresis		(lb)	4.0	4.0	4.0
RUDDER					
Initial	F_{RP}/δ_{RP}	(lb/in.)	30.0		
	δ_r/δ_{RP}	(deg/in.)	8.0		
Final	F_{RP}/δ_{RP}	(lb/in.)	61.5	61.5	61.5
	δ_r/δ_{RP}	(deg/in.)	7.14	7.14	7.14
Breakout		(lb)	10.0	10.0	10.0
Hysteresis		(lb)	0	0	0

altitude. The minimum approach altitude was dictated by the degree of difficulty the evaluation pilot experienced in controlling the airplane. However, in no case was the minimum altitude much lower than 50 feet or higher than 150 feet. The task, then, was to arrive at this minimum altitude with the airplane in such a position and under control by the evaluation pilot that a landing could have been successfully executed from that point.

3.2.2 Evaluation Procedure

Two evaluations were planned for each flight. Each evaluation included landing approaches flown under both simulated IFR and VFR conditions. The ILS approaches were flown to runway 28R at Niagara Falls International Airport, Niagara Falls, New York. The approach speed used for all approaches was 135 knots. The TIFS configuration for the approaches prior to engagement of the VSS when in level flight was landing gear down, Fowler flaps at 30 degrees and direct lift flaps at 17 degrees. This combination of flap produced the appropriate angle of attack match with the model at the initial condition of VSS engagement.

During this phase of the experiment the TIFS gust alleviation system and the gust simulation system were not used because they were not fully optimized. A model-following variable stability system will tend to act as a limited bandwidth gust alleviation system when no turbulence inputs are fed to the model and the feedforward and feedback signals are inertial quantities. Therefore, the turbulence response experienced by the evaluation pilot was that portion of the normal TIFS airplane turbulence response not alleviated by the model-following loops.

The actual turbulence experienced was therefore an uncontrolled variable and the evaluation pilot was asked to report the level and effects of the turbulence in his comments.

A total of 36 evaluations of 17 different configurations was performed by three evaluation pilots. This total included 2 repeats of the same configuration by Pilot A. Pilot A performed 19 evaluations, Pilot B, 8 and Pilot C, 9.

The evaluation pilots were not informed about the configurations to be evaluated on any flight.

3.2.3 Evaluation Tasks

A typical sequence of tasks during each evaluation was as follows:

1. Familiarization with configuration
   - (a) Select control sensitivities (this was done on initial flight for each evaluation pilot, then held fixed for each pilot for further configurations).
   - (b) Determine trimability - ability to stabilize and trim.
   - (c) Perform maneuvers as considered necessary to determine ability to make precise changes in bank angle and heading.
2. Radar vectored track to ILS final approach course (1800 to 2000 feet).
3. Visual ILS approach from outside outer marker to minimum approach altitude (normally 50 to 100 feet).

4. Visual waveoff and climb with radar vectors for positioning to intercept localizer course several miles outside of outer marker.

5. Hooded ILS approach from outside outer marker to ILS minimum altitude at middle marker (200 feet).

6. Visual final approach to minimum altitude.

7. Visual waveoff followed by a short intercept of the localizer course, then following radar vectors while hooded so as to arrive at the middle marker altitude with a 200 foot lateral offset to the runway.

8. Visual final approach from the 200 foot lateral offset to line up with the instrument runway.

Note: The visual level-off at minimum altitude for most approaches was followed by making heading changes as deemed appropriate by the evaluation pilot to assess lineup capability at low altitude when flying down the runway.

The initial flight for each pilot was considered a pre-evaluation flight and allowed the pilot to become familiar with the evaluation procedure and use of the comment card while making evaluation comments. It was during this pre-evaluation flight that the pilot was allowed to select his control sensitivities which were then held fixed for his remaining configurations. Pilot A, however, did make a change in his control sensitivities after flying 2 evaluation flights. These values are shown on page 35. The configuration flown by all pilots for their pre-evaluation flight was the same configuration, namely, the baseline configuration.

Pilot B indicated he preferred lighter forces on all controls compared to the values he used for all his evaluations. Although he was given the opportunity to reduce his control forces to a value considered optimum to him, he chose to use the values as listed because he felt he could separate the effects of the non-optimum forces from the effects of the other changes in lateral-directional dynamics.

3.2.4 Pilots

Three evaluation pilots participated in the program. A summary of their experience is presented below:

Pilot A: CAL research pilot with experience as an evaluation pilot in handling qualities investigations using variable stability aircraft and ground simulators. His flight experience of 9100 hours includes 6000 hours in multi-engine aircraft in addition to fighters, trainers and helicopters.

Pilot B: North American B-1 project pilot with extensive experience in flight test. Graduate of the USAF Aerospace Research Pilots School with 4500 hours of diversified flying including fighter, bomber, trainer and helicopter.

Pilot C: NASA Ames research pilot who served as project pilot on various handling qualities studies using both aircraft and ground simulators. His flight experience of 4000 hours includes experience in both fighters and large transports.

3.2.5 Pilot Comment and Rating Data

Pilot comments and ratings were the primary data obtained. In order to standardize the order and organization of the pilot comments, the evaluation pilots were requested to use the Pilot Comment Card which is reproduced as Table III.

3.2.6 Model Validation Procedures

In order to help the analyst document the pilot comment data as well as to provide him with a quick look at pilot comments immediately following an evaluation flight, the comment card included tabulated comment choices for various questions. The evaluation pilot was asked to check his appropriate comment choice in addition to tape recording his comments to these and other questions on the comment card.

TABLE III PILOT COMMENT CARD

Flight No. ____________
Eval. Pilot ____________
Date ____________

COMMENT CARD

Check After
Tape Recorded

1. Coordination in turns.

a.

		Small	Moderate	Large
Initial Rudder Used	With			
	Against			
	Zero			
Secondary Rudder Used	With			
	Against			
	Zero			
Steady State Rudder Used	With			
	Against			
	Zero			

b. Ease in accomplishing turns.

Easy	
Moderately Difficult	
Very Difficult	

c. What factors contributed to your choice of the assessment given in b. above? ______

2. Initial response to aileron only input.

a. Yawing motion at start of turn.

Turns too Fast	
Just Right (Coordinated)	
Nose Hangs Up (Turns too slow or not at all)	
Turns Wrong Way First	

b. If nose hangs up, how long does this condition exist? Approx.____ seconds.

c. Comment on and assess the degree of lateral acceleration experienced. ______

3. Ease of achieving a desired bank angle.

a.

Easy	
Moderately Easy	
Moderately Difficult	
Very Difficult	

-2-

Flight No. ____________
Eval. Pilot ____________
Date ____________

Check After
Tape Recorded

b. What factors contributed to your choice of the assessment given in a. above? ______

c. Overshoot tendency of bank angle in roll mode.

None	
Slight	
Moderate	

4. Oscillatory characteristics (lateral-directional).

a. Magnitude and mode.

	Open-Loop		Closed-Loop	
	Roll	Yaw	Roll	Yaw
Small				
Moderate				
Large				

b. How much damping? Is it enough? ______

c. How was the oscillation controlled (ease and control used)?

	Aileron	Rudder	Both
Did not control it			
Easy to control			
Moderately easy to			
Difficult to			

d. How was the oscillation excited (ease and input)?

	Aileron	Rudder	Turbulence
Didn't excite it			
Easy to			
Moderately easy to			
Difficult to			

e. If one of the controls not used, so state. ______

f. Spiral, did it influence your task performance? Did you notice any change in your technique due to spiral? ______

TABLE III CONTINUED

-3-

Flight No. ____________
Eval. Pilot ____________
Date ____________

Check After
Tape Recorded

5. Control feel.

a. Force to make airplane respond as desired.

	Aileron	Rudder	Elevator
Too light			
Good			
Too Heavy			

If unaware of this characteristic or if unimportant, so state. ______

b. Gradient (travel associated with these forces).

	Aileron	Rudder	Elevator
Too small			
Reasonable			
Too large			

If unaware of gradient, or if appeared unimportant, so state. ______

c. Maximum travel.

	Aileron	Rudder	Elevator
Too small			
Reasonable			
Too large			

If unaware of extent of travel, or if appeared unimportant, so state. ______

d. Breakout forces, define what you see, if anything.

	Aileron	Rudder	Elevator
Too light			
Good			
Too heavy			

If unaware of this characteristic, or if unimportant, so state. ______

e. Deadband - did you notice any? If so, was it:

	Aileron	Rudder	Elevator
Good			
Too much			

If unaware of this characteristic, or if unimportant, so state. ______

-4-

Flight No. ____________
Eval. Pilot ____________
Date ____________

Check After
Tape Recorded

6. Do longitudinal control inputs cause excessive or undesirable lateral-directional airplane motions? ______

7. Do lateral-directional control inputs cause excessive or undesirable longitudinal airplane motions? ______

8. ILS beam capture.

a.

	Localizer	Glide Slope
Easy		
Moderately Difficult		
Very Difficult		

b. What factors contributed to your choice? ______

9. Ease of rolling out of a desired heading (or bank angle for flight director).

a.

	Heading VFR	Heading IFR	Bank Angle
Easy			
Moderately Difficult			
Very Difficult			

b. What factors contributed to your choice? ______

10. ILS beam tracking ability (ability to make small corrections).

a.

	Localizer	Glide Slope	Airspeed
Easy			
Moderately Difficult			
Very Difficult			

b. What factors contributed to your choice? ______

11. Ability to make small bank angle corrections.

a.

Easy	
Moderately Easy	
Moderately Difficult	
Very Difficult	

b. What factor contributed to your choice above? ______

TABLE III CONCLUDED

-5-

Flight No. ____
Eval. Pilot ____
Date ____

Check After
Tape Recorded

12. Ability to pick up a wing.

more than adequate	
adequate	
inadequate	

13. Roll authority (maximum roll rate).

adequate or more	
just barely adequate	
inadequate	

14. Discuss trim changes.

a. Size with respect to power, speed, attitude or anything else observed.

small	
moderate	
large	

b. Ability to compensate with respect to the items of (a.).

easy	
moderately difficult	
very difficult	

____

15. If you had been flying in cruising flight with similar control characteristics for a considerable length of time (hours), do you feel that fatigue would be a significant factor in enabling you to safely terminate your mission? ____

16. Do you consider your workload to be:

small	
moderate	
large	

17. a. What are the most objectionable features of the configuration just completed?

b. Does some feature stand out as particularly good? What? ____

-6-

Flight No. ____
Eval. Pilot ____
Date ____

Check After
Tape Recorded

18. Turbulence level on approach. Rating ____

Light	
Moderate	
Heavy	

19. How well do you feel you performed the various segments of the mission? ____

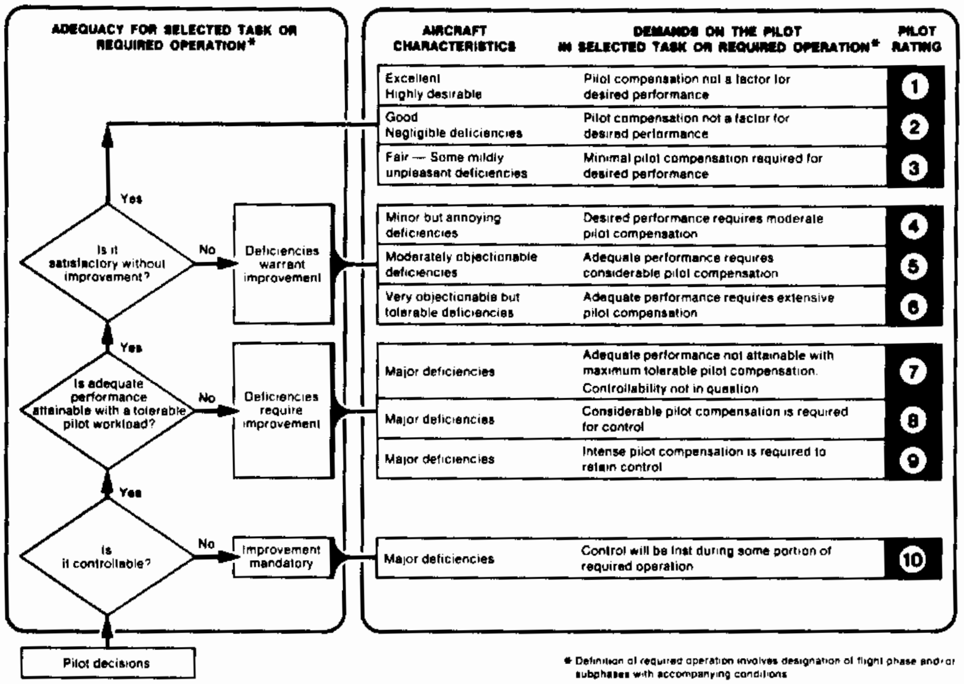
20. Did you notice any apparent simulation or navigational deficiencies or malfunctions during the mission? ____

21. Configuration Rating ____

If possible - what salient features dictated this choice of ratings? ____

It was required that the evaluation pilot comment on the items listed on the comment card at the completion of each evaluation, but he was free also to comment at any time during the evaluation that he felt it appropriate. As indicated by Item 21 on the comment card, the pilot was finally asked to assign a pilot rating for the configuration after completing the comments. This rating was given by the pilot in accordance with the Cooper-Harper Handling Qualities Rating Scale as described in Reference 12, and shown in Figure 11. Pilot comments for each configuration are contained in Appendix VI.

The pilot rating assigned by the evaluation pilot to each configuration included the effects that turbulence had on the handling qualities. Therefore, in addition to the rating of the overall configuration, an alphabetical turbulence rating was assigned which was an assessment of the effects on the handling qualities of turbulence. These ratings were given in accordance with the turbulence effect rating scale shown in Table IV, which has been used by CAL in other flight research programs (e.g., AFFDL-TR-67-98, July 1967), to indicate the effect of turbulence on pilot workload and task performance. Data on measured turbulence appears in Appendix VII.



* Definition of required operation involves designation of flight phase and/or subphases with accompanying conditions

FIGURE 11 COOPER-HARPER HANDLING QUALITIES RATING SCALE

TABLE IV TURBULENCE EFFECT RATING SCALE

INCREASE OF PILOT EFFORT WITH TURBULENCE	DETERIORATION OF TASK PERFORMANCE WITH TURBULENCE	RATING
NO SIGNIFICANT INCREASE	NO SIGNIFICANT DETERIORATION	A
MORE EFFORT REQUIRED	NO SIGNIFICANT DETERIORATION	B
	MINOR	C
	MODERATE	D
BEST EFFORTS REQUIRED	MODERATE	E
	MAJOR (BUT EVALUATION TASKS CAN STILL BE ACCOMPLISHED)	F
	LARGE (SOME TASKS CANNOT BE PERFORMED)	G
UNABLE TO PERFORM TASKS		H

Model Validation Procedures

When using a model-following type of variable stability airplane for research, the verification that a particular dynamic configuration is being flown consists of checking two basic items:

(1) Ascertaining that the correct model has been set up on the analog computer, i.e., the pots defining stability derivatives were set correctly, and that the analog was producing the correct time histories for selected control inputs.

(2) Ascertaining that the TIFS responses in flight were in fact following the analog generated responses for pilot control inputs.

Item 1 was accomplished in the following ways:

1. A static voltage check was performed on the analog setup to verify proper mechanization of equations of motion.

2. Three-degree-of-freedom digital computer time histories of model responses to model control inputs were compared with those generated for identical control inputs by the VSS model analog computer. This comparison was simplified by producing time history overlays from the digital computer responses which were then used to compare with the time

histories generated by the VSS model analog and recorded on the on-board strip chart recorder.

Item 2 was achieved by the following procedures in flight:

1. While using only the model computer on board, model computer responses on the strip chart were compared with digital computer time history overlays. The β , ϕ , and r responses for both δ_a and δ_r step inputs were compared as were the α , θ and V responses for δ_e step inputs.

2. Having ascertained this comparison, TIFS model-following responses to test control inputs were compared on-line on the strip chart with the model computer responses generated for these control inputs.

3. After satisfactory performance was verified in Step 2, TIFS model-following responses to pilot control inputs were similarly compared.

4. Continuous monitoring of model following was performed by Test Engineer No. 1 during the evaluation flying.

3.3 DATA ACQUISITION

The TIFS airplane is equipped with the following data acquisition equipment:

1. Four-channel Brush strip chart recorder.
2. Sixty-channel Ampex digital magnetic tape recorder.
3. Two Norelco cassette tape voice recorders.

The strip chart recorder, which incorporates the ability to select 10 different combinations of 4 output channels, was used continuously during flight to monitor model-following system performance. The digital magnetic tape recorder was used to acquire specific documentation records of responses to classic inputs and records of the evaluation ILS approaches for more detailed analysis after the flight. Specific data recorded on the magnetic tape recorder is listed in Appendix III.

One voice recorder was used exclusively to record evaluation pilot comments while the other was available when required to record pertinent TIFS crew intercommunications pertaining to model-following system and general airplane operation.

SECTION IV

DISCUSSION OF RESULTS

Table I of Section II listed the configurations evaluated in the Phase I research program in terms of stability derivative changes from the baseline configuration. The lateral-directional stability derivative variations are now listed below in Table V, for convenient reference for discussion of results in this section. The evaluation results will be discussed in terms of variations of stability and control derivatives as defined by the groupings shown below:

TABLE V

VARIATION OF STABILITY AND CONTROL DERIVATIVES

GROUP	VARIABLE	FIXED PARAMETERS	CONFIGURATIONS
A.1	$C_{n_{\delta_a}}$	BL	P-1, P-2, P-3, P-4
A.2	$C_{n_{\delta_a}}$	BL with $C_{l_\beta} = +5$ BL	P-6, P-14, P-16
A.3	$C_{n_{\delta_a}}$	BL with $C_{l_r} = +2$ BL	S-1, S-3, S-5
B.1	C_{l_β}	BL	P-1, P-6, P-7
B.2	C_{l_β}	BL with $C_{n_{\delta_a}} = +3$BL	P-2, P-14
B.3	C_{l_β}	BL with $C_{n_{\delta_a}} = +6$BL	P-4, P-16
B.4	C_{l_β}	BL with $C_{l_r} = +2$BL, $C_{n_{\delta_a}} = +3$BL	S-3, S-7
C.1	C_{n_p}	BL	P-1, P-8, P-9
C.2	C_{n_p}	BL with $C_{l_\beta} = +5$BL	P-6, P-12, P-13
D.1	C_{l_r}	BL	P-1, S-1, S-2
D.2	C_{l_r}	BL with $C_{n_{\delta_a}} = +3$ BL	P-2, S-3
D.3	C_{l_r}	BL with $C_{n_{\delta_a}} = +6$ BL	P-4, S-5

The lateral-directional modal parameters, certain transfer function numerator terms, and time histories of response to control inputs are included in Appendix IV for the configurations evaluated.

Later in this section, comparisons will be made between the configurations evaluated and specific lateral-directional requirements as defined in MIL-F-8785B(ASG). At that time additional grouping identification will be utilized as previously discussed in Section II.

4.1 EFFECT OF $C_{n_{\delta_a}}$ VARIATIONS ON PILOT RATING

Figure 12 indicates the change in pilot rating as $C_{n_{\delta_a}}$ was varied from the baseline configuration for Group A.1. For the baseline set of lateral-directional dynamics, the optimum pilot rating occurred as the yaw due to aileron was initially increased in a proverse sense from the baseline Configuration P-1. Further increase in proverse yaw due to aileron produced less degradation in pilot rating than that caused by introducing adverse yaw due to aileron. As $C_{n_{\delta_a}}$ was initially made more proverse from the baseline in P-2, the evaluation pilots reported less coordination required with rudder. Pilot C reported Configuration P-2 as a good two-control airplane. However, as $C_{n_{\delta_a}}$ was further increased in the proverse sense in P-4, the comments indicated difficulty in determining proper rudder usage. In both P-2 and P-4 complaints were made of the effect of increasing lateral acceleration with aileron inputs. The high proverse $C_{n_{\delta_a}}$ flown in P-4 caused an increasing overshoot tendency in bank angle and trouble when rolling out on heading. In contrast, when $C_{n_{\delta_a}}$ was made adverse in P-3, the pilots complained mainly of yawing oscillation and the large amounts of rudder required

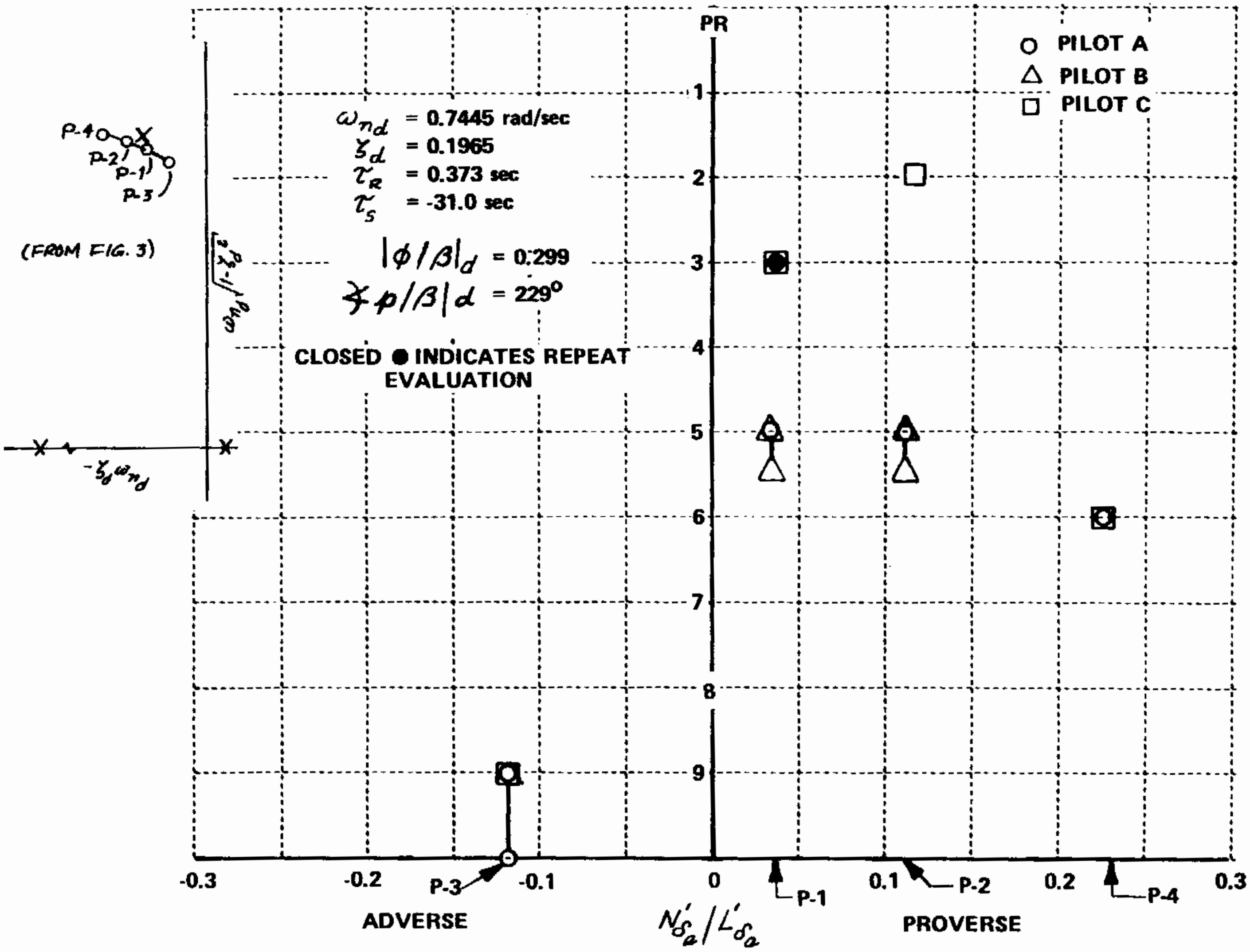


FIGURE 12 PILOT RATING AS A FUNCTION OF $N'_{\delta_a}/L'_{\delta_a}$ FOR GROUP A.1

to coordinate. Pilot C complained of a poorly damped directional mode which tended to be divergent unless he stayed on it with a lot of rudder. Pilot C rated this configuration (P-3) a 9, while Pilot A rated this configuration a 9 at best.

Group A.2 represents a group of configurations wherein the baseline parameters were changed due to increasing the C_{ℓ_β} to a value 5 times baseline, as indicated in Figure 13. Three values of proverse yaw due to aileron were examined. All configurations of this group were evaluated by Pilot A and P-14 was evaluated by a different pilot (Pilot C). The general trend of degradation of pilot rating with increasing proverse yaw due to aileron as noticed in Group A.1 is also evident in this grouping. The difference in rating reported by Pilots A and C for Configuration P-14 appears to be related to the effect of turbulence during the evaluation. Pilot C reported no turbulence and rated the configuration 2.5 with small workload while Pilot A reported moderate turbulence, rated the configuration 5, and considered the workload to be moderate. Again as noted in Group A.1, an increase in proverse yaw due to aileron caused a more objectionable level of lateral acceleration with aileron inputs.

In Configuration P-14, Pilot C reported a well harmonized airplane. This comment is comparable to his description of Configuration P-2 of Group A.1. Both these configurations have the same value of proverse yaw due to aileron. Discussions with Pilot C indicated that his evaluation technique involved less intentional aggressive maneuvering during the evaluation

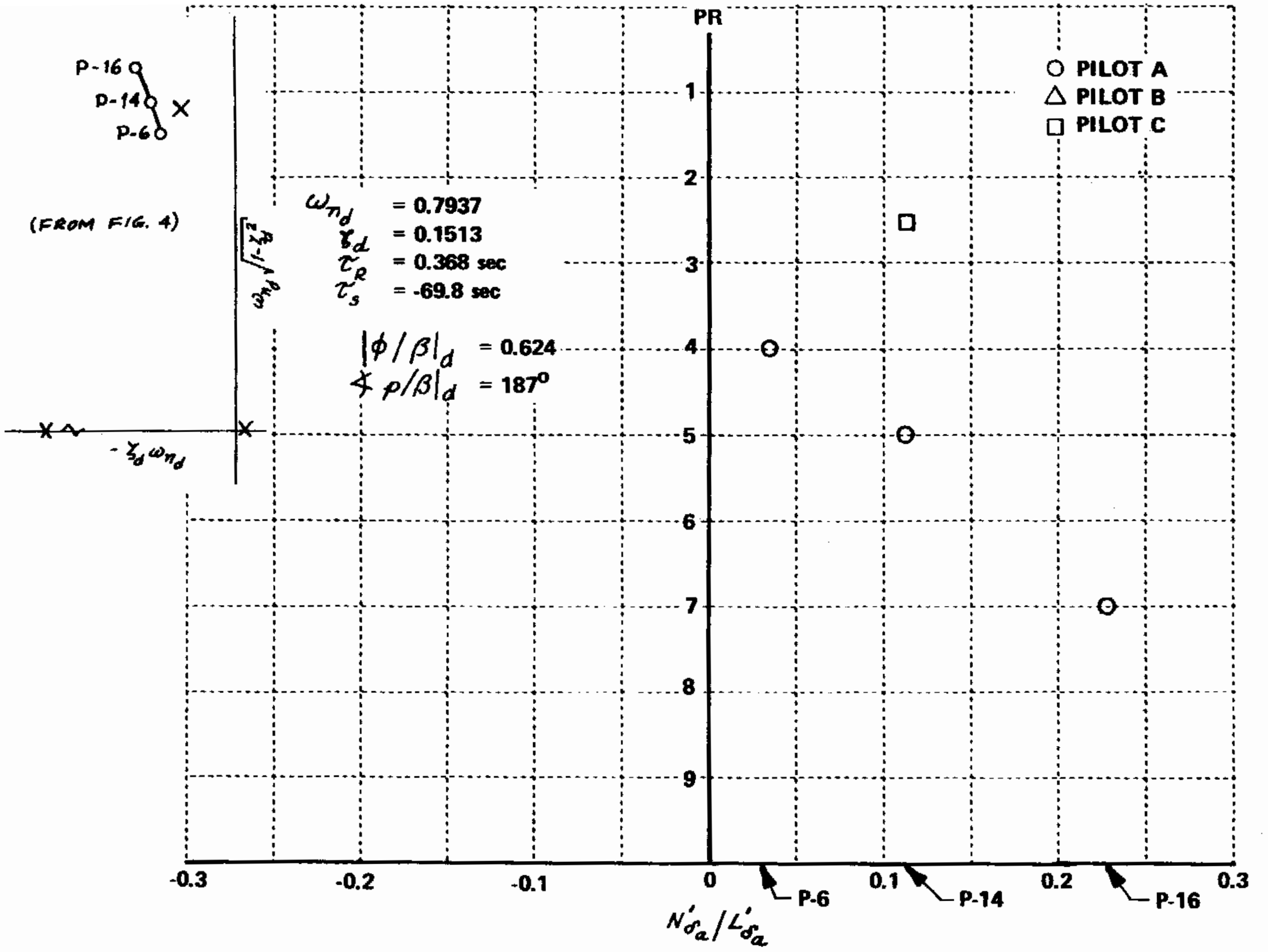


FIGURE 13 PILOT RATING AS A FUNCTION OF $N'_{\delta_a}/L'_{\delta_a}$ FOR GROUP A.2

than either Pilots A or B who purposely excited the airplane at times to observe the control requirements for abrupt disturbances. This intentional smoother flying by Pilot C coupled with the fact that the turbulence level during his evaluation of both configurations, P-2 and P-14, was lower than for the other pilots, is theorized to be the reason for his better rating of these configurations.

Group A.3 compares variations in pilot rating with changes in $C_{n_{\delta_a}}$ for a configuration defined by baseline stability derivatives but with C_{ℓ_r} increased to a value of 2 times baseline (see Figure 14). Yaw due to aileron values of baseline, 3 times baseline and 6 times baseline (all proverse) were investigated. The inter-pilot and intra-pilot rating variations for Configuration S-1 cannot be satisfactorily explained; however, the following observations concerning control usage are noted: (1) Comparison of Pilot A's control usage during ILS approaches for his two evaluations shows more rudder and less aileron for his repeat evaluation rated a 3 than for his initial evaluation rated a 6. (2) Pilot B made no attempt to use rudder during the ILS approaches and rated the configuration a 7. His control techniques would therefore appear to be comparable to those of Pilot A on his first evaluation which resulted in a rating of 6. It appears that the pilot rating for configuration S-1 is affected by rudder usage. In general, again, the trend in pilot rating with $C_{n_{\delta_a}}$ is similar to that noted in Groups A.1 and A.2 and the optimum region of pilot rating with yaw due to aileron appears to be a proverse value in the region of baseline to 3 times baseline for all three groups. This essentially agrees with the results reported in Reference 8.

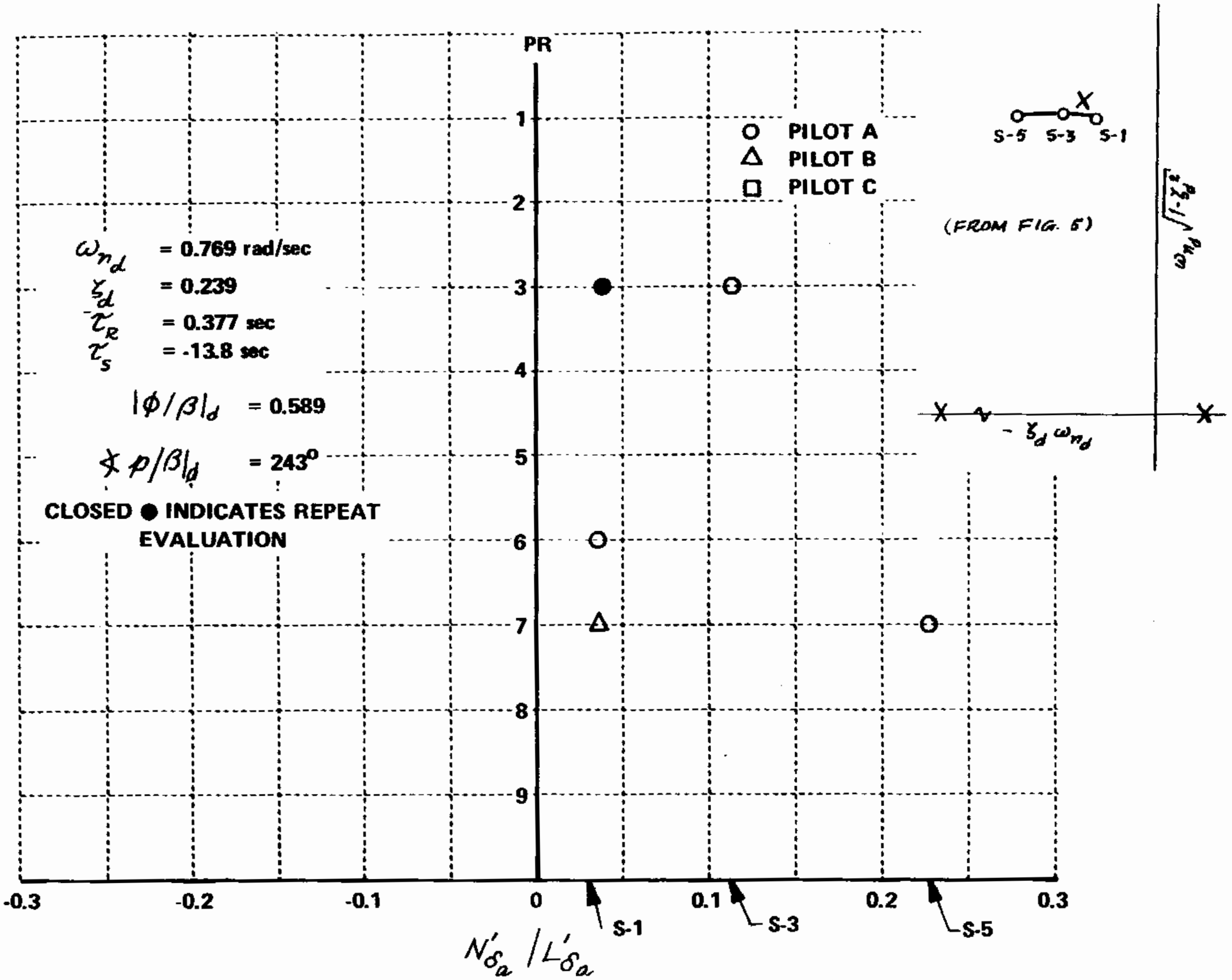


FIGURE 14 PILOT RATING AS A FUNCTION OF $N'_{\delta_a}/L'_{\delta_a}$ FOR GROUP A.3

4.2 EFFECT OF C_{ℓ_β} VARIATIONS ON PILOT RATING

Group B.1 illustrates the effect of increasing positive dihedral effect from the baseline configuration for a fixed baseline value of $C_{n_{\delta_a}}$. Groups B.2 and B.3 illustrate the effects of similar dihedral effect changes but for increased proverse yaw due to aileron for each grouping. Group B.4 shows the effect of changing dihedral effect coupled with the additional change in lateral-directional dynamics due to increasing C_{ℓ_r} from the baseline configuration. These four groups are presented in Figure 15. A detailed listing of modal parameters for each configuration is tabulated in Appendix IV. The effect of the stability derivative variations on modal parameters has been discussed in Section II.

This discussion will concentrate on the effect of the dihedral effect change. Examination of Group B.1 indicates pilot rating improves as dihedral effect is increased within the range investigated in this experiment. The pilot comments for the configurations with the lower values of dihedral effect indicate predominantly a yawing oscillation when the Dutch roll is excited. Controlling this oscillation with ailerons is less effective by the pilot and requires more rudder usage as a primary control. The pilot comments indicate that it was not easy to use rudder as a primary control for these oscillations and at times when rudder phasing was difficult to determine, its use was abandoned with the pilot accepting the resulting degraded oscillations. However, as dihedral effect was increased, e.g.,

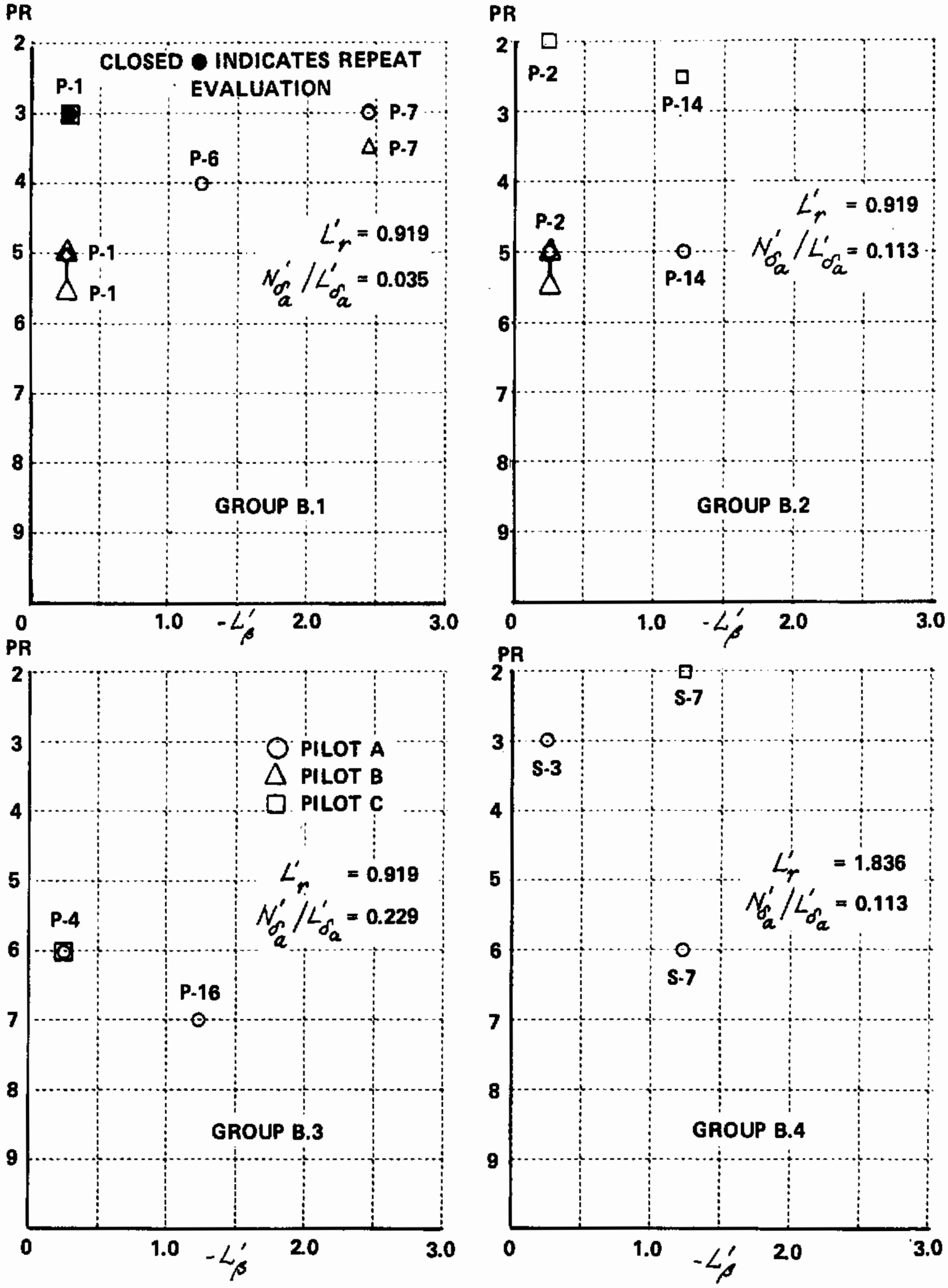


FIGURE 15 EFFECT OF L'_β ON PILOT RATING FOR GROUPS B. 1, B. 2, B. 3, B. 4

Configuration P-7, both pilots indicate that it became easier to use rudder effectively to control sideslip. It appears that, with the increasing dihedral effect from the very low baseline value for this group, the increase in $|\phi/\beta|_d$ provides the pilot with more motion cues which enable him to introduce stabilizing control inputs. Similar comments are reported in Reference 13.

Group B.2 includes only one variation in C_{l_β} from baseline (C_{l_β} = 5 BL) with an increased value of proverse $C_{n_{\delta_a}}$. Pilot A's ratings show no change with increasing C_{l_β} . Pilot C also indicates no significant change. Even though Pilot A and Pilot C themselves show no rating change for the C_{l_β} change, there is an inter-pilot variation of 3 pilot ratings (Pilot A rating a 5 and Pilot C rating a 2). Examination of pilot comments and flight records again indicates that Pilot C saw both Configurations P-2 and P-14 in a lower level of turbulence than did Pilot A. This appears to be a possible reason for the difference in pilot rating between the two pilots.

Group B.3 has a larger value of proverse $C_{n_{\delta_a}}$ than either B.1 or B.2. Increasing C_{l_β} in this group appears to have an almost insignificant effect on pilot rating as compared to the effect of the increased proverse yaw due to aileron seen on both configurations in this group. The pilot comments relate more to the increased lateral acceleration with aileron input and the difficulty in using rudder properly.

Group B.4 is essentially the same as B.2 except for the increase of C_{l_r} to 2 times baseline. Examination of the flight records indicates that the level of turbulence seen by Pilot C on Configuration S-7 is comparable to that seen by Pilot A on S-3. Comparison of these two ratings would indicate that for a low level of turbulence the change in pilot rating as a function of C_{l_β} was not significant. This is comparable with the ratings of Pilot C in the B.2 group which were also evaluated in light turbulence. Comparison of the ratings of Configuration S-7 between Pilots A and C is similar to that seen for Configurations P-2 and P-14 which were also evaluated in a higher level of turbulence by Pilot A than by Pilot C. It would thus appear that the variation of C_{l_β} in the Group B.4 configurations has no significant effect on pilot rating if the configurations are evaluated at comparable levels of turbulence.

4.3 EFFECT OF C_{n_p} VARIATIONS ON PILOT RATING

Groups C.1 and C.2 are shown together on Figure 16. In general, for both Groups C.1 and C.2 the trend in pilot rating indicates a degradation for changes in C_{n_p} from the baseline value in both the adverse and the proverse sense. In addition, Figure 16 also indicates that for both variations of C_{n_p} from baseline a significant improvement in pilot rating was achieved for a higher value of positive dihedral in Group C.2. In Group

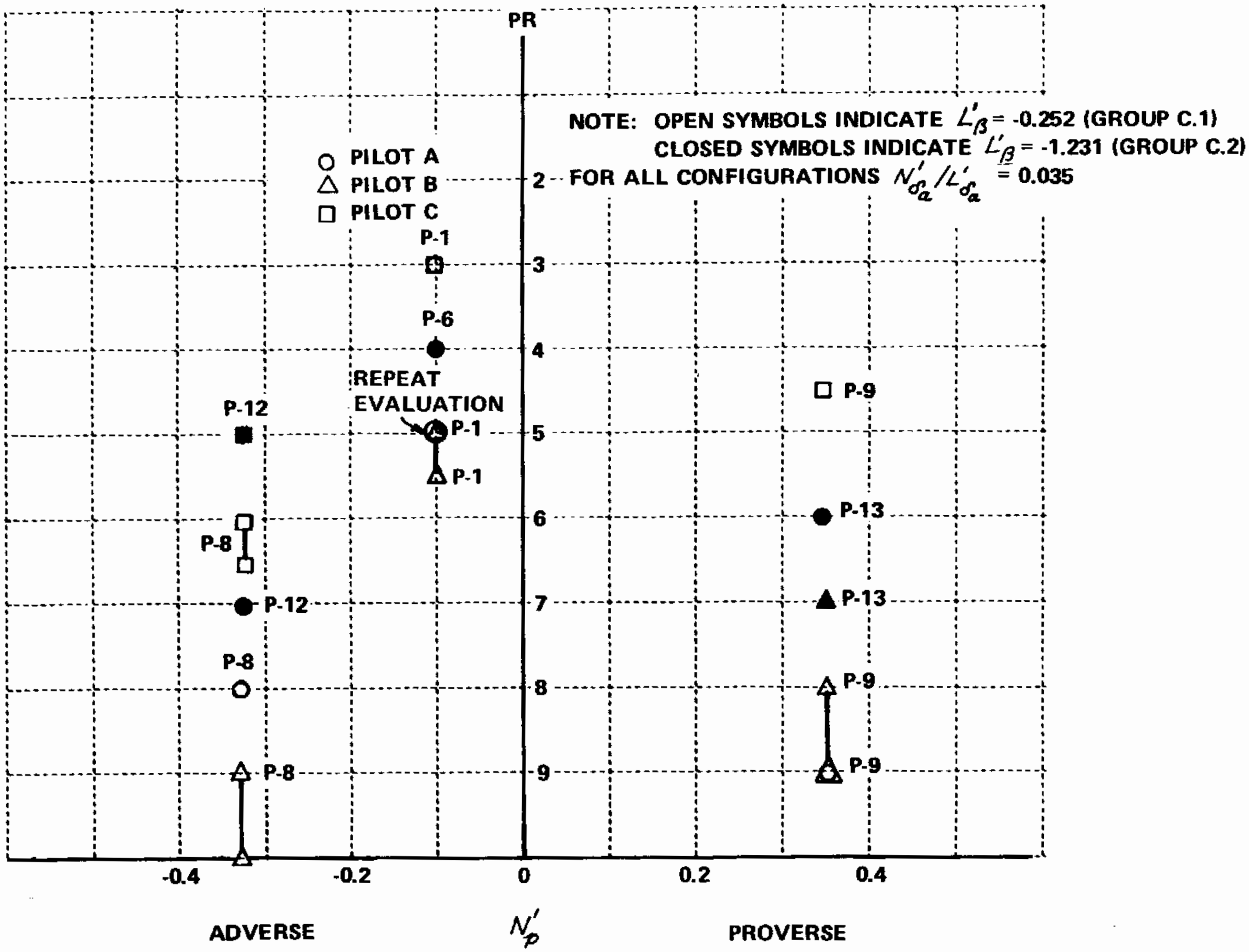


FIGURE 16 EFFECT OF VARIATIONS IN N'_p AND L'_β ON PILOT RATING ($N'_{\delta_a}/L'_{\delta_a} = 0.035$)

C.1, examination of the pilot comments and flight records indicates that when C_{n_p} was made more adverse than the baseline (Configuration P-8), it became mandatory to use the rudder in an attempt to coordinate. Also, it was difficult for the pilot to determine proper use of the rudder because of the long wallowing directional oscillation which was induced by roll rate. When C_{n_p} was changed in the proverse sense from the baseline (Configuration P-9), pilot comments indicate that the most objectionable feature was the excessive proverse yaw and the difficulty in rudder phasing when making turns. Flight record examination indicates that the pilots used either no rudder or less rudder on the ILS approaches of Configuration P-9 than for Configuration P-8. The major difference on Configuration P-9 was that, although the airplane was rated poor, the pilot was able to maneuver the airplane without using rudder while accepting degraded maneuvers and control capability as compared to Configuration P-8 where rudder was mandatory to even achieve a poor level of control capability.

The pilot comments for Group C.2 follow the same pattern as reported in Group C.1 and although Group C.2 as a whole was rated better than Group C.1, there appears to be no conclusive reason listed in the comments to explain the rating difference.

4.4 EFFECT OF C_{ℓ_r} VARIATIONS ON PILOT RATING

Figure 17 illustrates the effect of C_{ℓ_r} variations for 3 different values of $C_{n_{\delta_a}}$. Because of the pilot rating scatter of Group D.1 no

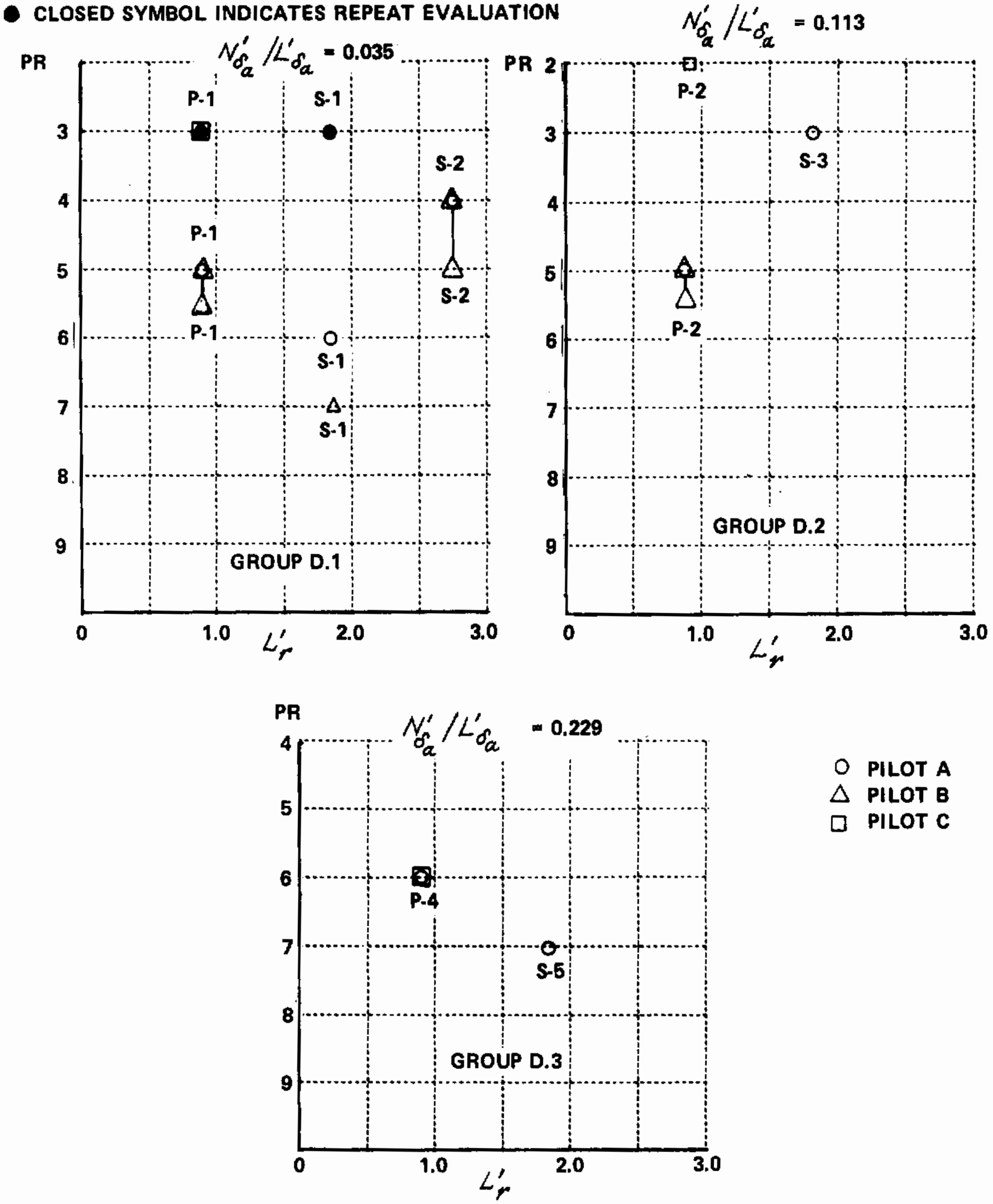


FIGURE 17 EFFECT OF VARIATIONS IN L'_r ON PILOT RATING

definite trend of pilot rating with C_{l_r} can be determined. The discussion on page 54 of pilot rating change with rudder usage does, however, shed some light on the scatter of the configuration S-1 ratings.

In Group D. 2, examination of pilot comments and flight records indicates that the effect of changes in C_{l_r} for the same level of turbulence can be determined by comparison of Configuration P-2 for Pilot C with Configuration S-3 for Pilot A. The reason for this comparison is that Configuration P-2 was evaluated by Pilots A and B with a higher level of turbulence. Under this condition it appears that for Group D. 2, increasing C_{l_r} resulted in a slight degradation in pilot rating. In Group D. 3, Pilot A evaluated Configurations P-4 and S-5 in essentially the same turbulence environment for both configurations and as in Group D. 2, increasing C_{l_r} resulted in a poorer pilot rating. Within the limits of the variation in C_{l_r} investigated it appears that the degradation in pilot rating with C_{l_r} is not dependent on the level of proverse yaw due to aileron.

4.5 COMPARISON OF PILOT RATINGS WITH LATERAL-DIRECTIONAL REQUIREMENTS OF MIL-F-8785B(ASG)

To facilitate this comparison, it was indicated in Section II (Figure 7) that the configurations evaluated would tend to group together in the $\Delta\beta_{max}/k$ vs. ψ_β requirement plane. The comparisons will be based on these groupings.

Group I

Group I consists of Configurations P-1, S-1, S-2, P-6 and P-7. This group would satisfy the $\Delta\beta_{max}/k$ requirement for a Level 1 airplane. The following table presents the pilot ratings for the configurations in this group. Bracketed pilot ratings indicate the pilot rating obtained on a repeat evaluation of that configuration.

CONFIGURATION	PILOT RATING A	B	C
P-1	5(3)	5-5.5	3
P-6	4	--	--
P-7	3	3.5	--
S-1	6(3)	7	--
S-2	4	4-5	--

No. of Level 1 ratings - 5

No. of Level 2 ratings - 6

No. of Level 3 ratings - 1

The following observations are made concerning this group: (1) Configurations P-1, P-6, and P-7 do not satisfy the Level 1 minimum $\zeta_d \omega_{n_d}$ Dutch roll requirement, yet the ratings given these configurations indicate an almost equal probability of these configurations being either Level 1 or Level 2. (2) Configurations S-1 and S-2 meet the Level 1 minimum $\zeta_d \omega_{n_d}$ Dutch roll requirement,however, these configurations do not meet the Level 1 or Level 2 spiral stability requirement. These configurations (S-1 and S-2) show a strong tendency to be rated a Level 2.

In general for this grouping of configurations the $\Delta\beta_{max}/k$ requirement appears to be realistic, however the Dutch roll and spiral requirements may be conservative.

Group II

Group II consists of Configurations P-2, P-14, S-3 and S-7. These configurations would also satisfy the Level 1 $\Delta\beta_{max}/k$ requirement. The following table presents the pilot rating for the configurations in Group II.

	PILOT RATING		
CONFIGURATION	A	B	C
P-2	5	5-5.5	2
P-14	5	--	2.5
S-3	3	--	--
S-7	6	--	2

No. of Level 1 ratings - 4

No. of Level 2 ratings - 4

No. of Level 3 ratings - 0

Pilot C's comments for these configurations indicated he thought them to be well harmonized, two-control airplanes. Examination of the turbulence rating given by the pilots for these configurations clearly indicates that there is a strong correlation with the degraded ratings in this group and the turbulence rating.

The following observations are made for this group: (1) For low levels of turbulence, the configurations in this group are rated Level 1, however as turbulence increased, these configurations were rated Level 2. (2) Configurations P-2 and P-14 do not satisfy Level 1 Dutch roll requirements, however the above data indicates that the Dutch roll requirement may be conservative for these configurations assuming that the ratings given them by Pilot A reflected the higher turbulence level. (3) Configurations S-3 and S-8 indicate that the spiral stability requirement may be conservative. (4) A difference in evaluation techniques for Configurations P-2, P-14 has been previously discussed on page 54 .

Group III

Group III consists of Configurations P-4, P-9, P-13, P-16 and S-5. These configurations do not satisfy either the Level 1 or Level 2 $\Delta\beta_{max}/k$ requirements of MIL-F-8785B(ASG). Group III pilot ratings are listed in the following table.

CONFIGURATION	PILOT RATING A	 B	 C
P-4	6	--	6
P-9	9	8-9	4.5
P-13	6	7	--
P-16	7	--	--
S-5	7	--	--

No. of Level 1 ratings - 0

No. of Level 2 ratings - 4

No. of Level 3 ratings - 5

Although the pilot ratings are almost equally split between Level 2 and Level 3 for these configurations, examination of the pilot comments indicates that extreme difficulties were encountered in making accurate heading changes to line up with the runway during the terminal part of the approach.

In light of these pilot comments, it is felt that the present $\Delta\beta_{max}/k$ Level 2 boundary in MIL-F-8785B(ASG) is justifiable for these configurations with relatively large proverse yaw due to aileron or roll rate.

Group IV

Group IV consists of Configurations P-8 and P-12. These configurations do not satisfy the $\Delta\beta_{max}/k$ Level 1 requirements but do satisfy the Level 2 requirement of MIL-F-8785B(ASG). The pilot ratings for Group IV are listed below:

CONFIGURATION	PILOT RATING A	PILOT RATING B	PILOT RATING C
P-8	8	9-10	6-6.5
P-12	7	--	5

No. of Level 1 ratings - 0

No. of Level 2 ratings - 2

No. of Level 3 ratings - 3

Configuration P-8 satisfies Level 1 Dutch roll requirements, Level 1 $\varphi_{osc}/\varphi_{AV}$ and Level 2 $\Delta\beta_{max}/k$ requirements. Configuration P-12 satisfies Level 2 Dutch roll requirements, Level 1 $\varphi_{osc}/\varphi_{AV}$ and Level 2 $\Delta\beta_{max}/k$ requirements. Pilot comments associated with these configurations indicate difficult heading control, especially for Configuration P-8, which exhibited extreme yawing oscillations when making bank angle and heading corrections. It would appear that the sideslip excursion requirement of MIL-F-8785B(ASG) may be too lenient, for configurations in this group.

Group V

Group V consists of only one configuration, namely P-3 which was the only configuration flown with adverse yaw due to aileron. Configuration P-3 fails to meet either Level 1 or Level 2 $\varphi_{osc}/\varphi_{AV}$ and $\Delta\beta_{max}/k$ requirements of MIL-F-8785B(ASG). Pilot A rated this configuration 9 to 10 while Pilot C rated it 9. The pilot comments definitely indicate that the adverse yaw due to aileron required considerable rudder compensation to control the predominantly yawing oscillations excited by aileron control. The exclusion of this configuration by the sideslip excursion requirement for Level 2 Class III airplanes is proper; however, under the present application of the specification, the configuration could be considered Level 3. The results of this investigation indicate that this configuration is on the border line of controllability and that possibly a Level 3 boundary on sideslip excursion would be in order to exclude such configurations as bare-airplane augmentation-failed vehicles.

4.6 SUMMARY OF PILOT RATINGS

Table VI presents the pilot ratings for all configurations evaluated in the Phase I in-flight research program. Repeat evaluation ratings are shown in brackets. For convenience of the reader, the groups in Section IV in which the configuration pilot ratings are discussed are also presented.

TABLE VI
SUMMARY OF PILOT RATINGS

Configuration	Pilot A	Pilot B	Pilot C	Discussed in Groups
P-1	5 (3)	5 - 5.5	3	A.1, B.1, C.1, D.1
P-2	5	5 - 5.5	2	A.1, B.2, D.2
P-3	9 - 10	---	9	A.1,
P-4	6	---	6	A.1, B.3, D.3
P-6	4	---	---	A.2, B.1, C.2
P-7	3	3.5	---	B.1
P-8	8	9 - 10	6 - 6.5	C.1
P-9	9	8 - 9	4.5	C.1
P-12	7	---	5	C.2
P-13	6	7	---	C.2
P-14	5	---	2.5	A.2, B.2
P-16	7	---	---	A.2, B.3
S-1	6 (3)	7	---	A.3, D.1
S-2	4	4 - 5	---	D.1
S-3	3	---	---	A.3, B.4 D.2
S-5	7	---	---	A.3, D.3
S-7	6	---	2	B.4

Section V

SUMMARY AND CONCLUSIONS

An investigation to determine the effects of variations in lateral-directional stability and control derivatives for a Class III airplane in the landing approach phase was conducted using the USAF/CAL Total In-Flight Simulator (TIFS). A summary of the results and the conclusions drawn is listed below:

(1) The capability of the TIFS airplane as a research facility for handling qualities investigations was clearly demonstrated on this program based on the level of model following achieved during this in-flight investigation and the consensus of the evaluation pilots as to the realism of the simulation.

(2) With the lateral-directional dynamics of the baseline configuration ($\omega_{n_d} \approx .74$ rad/sec, $\zeta \approx .2$, $|\phi/\beta|_d \approx .3$, $\tau_R = .37$, $T_{2_s} \approx 21$ sec), the optimum pilot rating occurred with proverse value of $N'_{\delta_a}/L'_{\delta_a}$ defined in a body axis system in the vicinity of +.1. Further increases in proverse yaw due to aileron resulted in a degradation of pilot rating associated with undesirable initial lateral acceleration when using aileron and difficulties in controlling yawing oscillations. For adverse yaw due to aileron, Configuration P-3 ($N'_{\delta_a}/L'_{\delta_a} = -.11$), airplane controllability by the pilot was in question (Figure 12).

(3) Proverse yaw due to aileron in the region of $N'_{\delta_a}/L'_{\delta_a} \approx .1$ was also shown to be optimum for configurations with increased dihedral effect (C_{ℓ_β}) or increased roll due to yaw rate (C_{ℓ_r}) (Figures 12, 13, and 14).

(4) For a low value of proverse yaw due to aileron ($N'_{\delta_a}/L'_{\delta_a} = .035$), increasing dihedral effect (C_{ℓ_β}) or effective dihedral as defined by $\measuredangle \frac{p}{\beta}\Big|_d$ (see Table II) produced a slight improvement in pilot rating. For larger proverse yaw due to aileron ($N'_{\delta_a}/L'_{\delta_a} = .1125$ and $.2287$), increasing dihedral effect from $L'_\beta = -.2517$ to $L'_\beta = -1.2312$ had no significant effect on pilot rating (Figure 15).

(5) For the baseline configuration, increases in C_{n_p} in either the proverse or adverse sense from the baseline value resulted in degraded pilot ratings (Figure 16).

(6) For the configurations with $C_{n_p} = \pm 3BL$($N'_p = -.3301$ and $+.3482$), a significant improvement in pilot rating was achieved when the level of positive dihedral effect was increased; however, the resultant pilot rating was in general poorer than that for the baseline (Figure 16).

(7) Increases in C_{ℓ_r} from the baseline value resulted in a slight degradation of the pilot rating (Figure 17).

(8) Interpilot and intrapilot rating differences appeared to be related to the turbulence level experienced during the evaluations. The effects of turbulence on the Level requirements of MIL-F-8785B(ASG) should be systematically investigated for low frequency, low roll-to-sideslip ratio Dutch roll modes.

(9) For the configurations investigated in this program, the Level 1 sideslip excursion requirement, 3.3.2.4.1 of MIL-F-8785B(ASB), appears to be realistic for low levels of turbulence and becomes too lenient as turbulence level is increased. The indicated Level of compliance with this requirement from analytical studies had good correlation with pilot ratings achieved in the in-flight program.

(10) For the configurations evaluated in this program, the Level 2 sideslip excursions requirement, 3.3.2.4.1 of MIL-F-8785B(ASG), appears realistic for configurations with ψ_β in the vicinity of -360° but too lenient for configurations with $\psi_\beta \approx -200°$.

(11) A few configurations which did not satisfy the Level 1 minimum $\zeta_d \omega_{n_d}$ Dutch roll requirement of paragraph 3.3.1.1 of MIL-F-8785B(ASG) were rated 3.5 or better. Further

handling qualities research is required to determine the levels of acceptability of configurations with low frequency Dutch roll modes.

(12) A bare airframe augmentation-failed Level 3 boundary for the roll-sideslip coupling requirements (3. 3. 2. 4. 1) boundary of MIL-F-8785B(ASG) may be warranted.

(13) The configurations evaluated in this program were typically characterized by a long period Dutch roll mode and an unstable spiral mode. For many of these configurations it was either difficult or impossible to make the p_{osc}/p_{AV} measurement as defined in MIL-F-8785B(ASG), paragraph 3. 3. 2. 2. 1. Although this measurement may not be critical as an index of the level of handling qualities because of the low $|\phi/\beta|_d$ for these configurations, it is suggested that the p_{osc}/p_{AV} requirement be reviewed for configurations with similar modal characteristics. The purpose of such a review should be the determination of a more appropriate measure of the intent of this requirement or in lieu of this, guidance should be provided for using agencies.

(14) For a Class III airplane in Flight Phase Category C, the Level 2 spiral stability requirement of MIL-F-8785B(ASG), paragraph 3.3.1.3, appears to be too restrictive (see pages 65 and 66).

Appendix I

Model Equations (at model cg)

The equations of motion are presented in the non-orthogonal axis system described in Reference 2.

Longitudinal Equations

The X Force equation in a wind axis system is

$$m\dot{V}_I = -mg\sin\gamma - \frac{1}{2}\rho V^2 S C_D + T_x\cos\alpha_I\cos\beta_I + T_z\sin\alpha_I\cos\beta_I \qquad (1.0)$$

If the thrust is assumed to be parallel to the fuselage reference line ($T = T_x, T_z \approx 0$), and assuming $\cos\alpha_I = 1$, $\sin\alpha_I = \alpha_I$, $\cos\beta_I = 1$, $\sin\beta_I = \beta_I$,
then the above equation becomes

$$\dot{V}_I = -g\sin\gamma - \frac{1}{2}\frac{\rho}{m}V^2 S C_D + \frac{T}{m} \qquad (1.1)$$

where $\sin\gamma = \sin\theta - \beta_I\sin\phi\cos\theta - \alpha_I\cos\theta\sin\phi$ (1.2)

The Z Force Equation in a body axis system can be written as

$$mg\cos\phi\cos\theta + \frac{1}{2}\rho V^2 S C_z + \cancelto{0}{T_z} = m\dot{w}_I + m(-q u_I + p v_I) \qquad (2.0)$$

where

$$w_I = V_I\sin\alpha_I\cos\beta_I \qquad (2.1)$$

$$u_I = V_I\cos\alpha_I\cos\beta_I \qquad (2.2)$$

$$v_I = V_I\sin\beta_I \qquad (2.3)$$

and

$$\dot{w}_I = V_I\sin\alpha_I(-\dot{\beta}_I\sin\beta_I) + \cos\beta_I(V_I\dot{\alpha}_I\cos\alpha_I + \dot{V}_I\sin\alpha_I)$$

introducing a small angle approximation on α_I, β_I

$$\frac{\dot{w}_I}{V_I} = -\dot{\beta}_I\alpha_I\beta_I + \dot{\alpha}_I + \alpha_I\frac{\dot{V}_I}{V_I} \qquad (2.4)$$

Neglecting the first term as a higher order term and using small angle approximations:

$$\beta_I \approx \frac{v_I}{V_I} \quad \text{and} \quad u_I \approx V_I$$

the Z force equation reduces to

$$\frac{g\cos\phi\cos\theta}{V_I} + \frac{1}{2m}\rho\frac{V^2 SC_z}{V_I} \doteq \dot{\alpha}_I + \alpha_I\frac{\dot{V}_I}{V_I} - q_I + p_I\beta_I$$

thus

$$\dot{\alpha}_I \doteq +\frac{1}{2m}\rho\frac{V^2}{V_I}SC_z + \frac{g}{V_I}\cos\phi\cos\theta + q_I - \frac{\alpha_I\dot{V}_I}{V_I} - p_I\beta_I \qquad (2.5)$$

The pitching moment equation in a body axis system can be written as

$$M_{aero} + z_T T_x - x_T T_z = I_{yy}\dot{q}_I + \left(I_{xx} - I_{zz}\right)p_I r_I + I_{xz}\left(p_I^2 - r_I^2\right) \qquad (3.1)$$

Assuming that the higher order inertial coupling terms can be neglected, and that $T = T_x$, $T_z = 0$

$$\dot{q}_I = \frac{1}{I_{yy}}\left(z_T T + \frac{\rho V^2 Sc}{2} C_m\right) \qquad (3.2)$$

Lateral Equations

The Y Force equation in a body axis system can be written as

$$mg\sin\phi\cos\theta + \frac{1}{2}\rho V^2 SC_y = m\dot{v}_I + m\left(ru_I - pw_I\right) \qquad (4.1)$$

where

$$v_I = V_I\sin\beta_I \qquad (2.3)$$

and

$$\dot{v}_I = V_I\dot{\beta}_I\cos\beta_I + \dot{V}_I\sin\beta_I \qquad (4.2)$$

$$\frac{\dot{v}_I}{V_I} = \dot{\beta}_I\cos\beta_I + \frac{\dot{V}_I}{V_I}\sin\beta_I \qquad (4.3)$$

assume small angles, such that

$$\frac{V_I}{V_I} = \dot{\beta}_I + \beta_I\frac{\dot{v}_I}{V_I} \qquad (4.4)$$

also

$$\frac{u_I}{V_I} \approx 1, \quad \frac{w_I}{V_I} \approx \sin\alpha_I \approx \alpha_I$$

then equation (4.1) becomes

$$\frac{g}{V_I}\sin\phi\cos\theta + \frac{1}{2m}\frac{\rho V^2 S C_y}{V_I} = \dot{\beta}_I + \beta_I\frac{\dot{V}_I}{V_I} + r_I - p_I\alpha_I \tag{4.5}$$

therefore

$$\dot{\beta}_I = \frac{1}{2m}\rho\frac{V^2}{V_I}SC_y + \frac{g}{V_I}\sin\phi\cos\theta - \frac{\beta_I\dot{V}_I}{V_I} - r_I + p_I\alpha_I \tag{4.6}$$

The rolling moment equation in a body axis system

$$L_{aero} = I_{xx}\dot{p}_I + q_I r_I\left(I_{zz}-I_{yy}\right) - \left(\dot{r}_I + p_I q_I\right)I_{xz} \tag{5.1}$$

or

$$\dot{p}_I = \frac{1}{I_{xx}}\left[L_{aero} + I_{xz}\dot{r}_I + I_{xz}p_I q_I - \left(I_{zz}-I_{yy}\right)q_I r_I\right] \tag{5.2}$$

neglecting $I_{xz}p_I q_I - \left(I_{zz}-I_{yy}\right)q_I r_I$ as a higher order term, the rolling moment equation becomes:

$$\dot{p}_I = \frac{1}{I_{xx}}\left[I_{xz}\dot{r}_I + \frac{1}{2}\rho V_T^2 SbC_\ell\right] \tag{5.3}$$

The yawing moment equation in a body axis system is

$$N_{aero} = I_{zz}\dot{r}_I + p_I q_I\left(I_{yy}-I_{xx}\right) + I_{xz}\left(q_I r_I - \dot{p}_I\right) \tag{6.1}$$

or

$$\dot{r}_I = \frac{1}{I_{zz}}\left[I_{xz}\dot{p}_I + p_I q_I\left(I_{xx}-I_{yy}\right) - I_{xz}q_I r_I + N_{aero}\right] \tag{6.2}$$

Again neglecting the higher order terms the above equation reduces to

$$\dot{r}_I = \frac{1}{I_{zz}}\left[I_{xz}\dot{p}_I + \frac{1}{2}\rho V^2 SbC_n\right] \tag{6.3}$$

The preceding equation assumes symmetrical thrust. Asymmetrical thrust capability was programmed on the model computer although it was not used.

The following auxiliary equations were programmed on the model computer

$$\dot{h} = V_I \sin\gamma \tag{7.1}$$

$$\sin\gamma = \sin\theta - \beta_I \cos\theta \sin\phi - \alpha_I \cos\theta \cos\phi \tag{1.2}$$

$$\rho = \rho_0 + \rho_h h + \rho_{h^2} h^2 \tag{7.2}$$

Euler angle equations were also programmed

$$p = \dot{\phi} - \dot{\psi} \sin\theta \tag{8.1}$$

$$q = \dot{\theta} \cos\phi + \dot{\psi} \cos\theta \sin\phi \tag{8.2}$$

$$r = \dot{\psi} \cos\theta \cos\phi - \dot{\theta} \sin\phi \tag{8.3}$$

Accelerations at the model pilot station were computed using the following equations. Only accelerations along the x and z axes were computed.

$$n_{z_p} \doteq n_{z_m} - \frac{1}{g} \, l_{x_p} \, \dot{q}_{I_m} \tag{9.1}$$

$$n_{y_p} \doteq n_{y_m} + \frac{1}{g} \left(l_{x_p} \dot{r}_{I_m} - l_{z_p} \dot{p}_{I_m} \right) \tag{9.2}$$

where n_{z_m} and n_{y_m} are defined by

$$n_{z_m} = \frac{1}{mg} \left(Z_{aero} + Z_T \right) \qquad \text{assume } Z_T = 0$$

$$= \frac{1}{mg} \left(\frac{1}{2} \rho V^2 S C_z \right) \approx \frac{1}{mg} \left(\frac{1}{2} \rho V^2 S \right) \left(-C_L - C_D \alpha_I \right) \tag{9.3}$$

$$n_{y_m} = \frac{1}{mg} \left(Y_{aero} \right) = \frac{1}{mg} \left(\frac{1}{2} \rho V^2 S C_y \right) \tag{9.4}$$

Engine Dynamics

The engine dynamics of the model to be simulated used a simple second-order system with no rate limits.

The anticipated engines were GE 9/F7B, rated at approximately 25,000 lb thrust per engine. The total thrust of the four engines was simulated by

$$\ddot{T} + 2\zeta\omega_n\dot{T} + \omega_n^2 T = \omega_n^2\left(\frac{T}{\delta_T}\right)\delta_T \tag{9.5}$$

where $\zeta = .8$

$\omega_n = 1.85$ rad/sec

$T/\delta_T = 1000$

To obtain a realistic idle power lever setting, a 30% power lever offset was programmed.

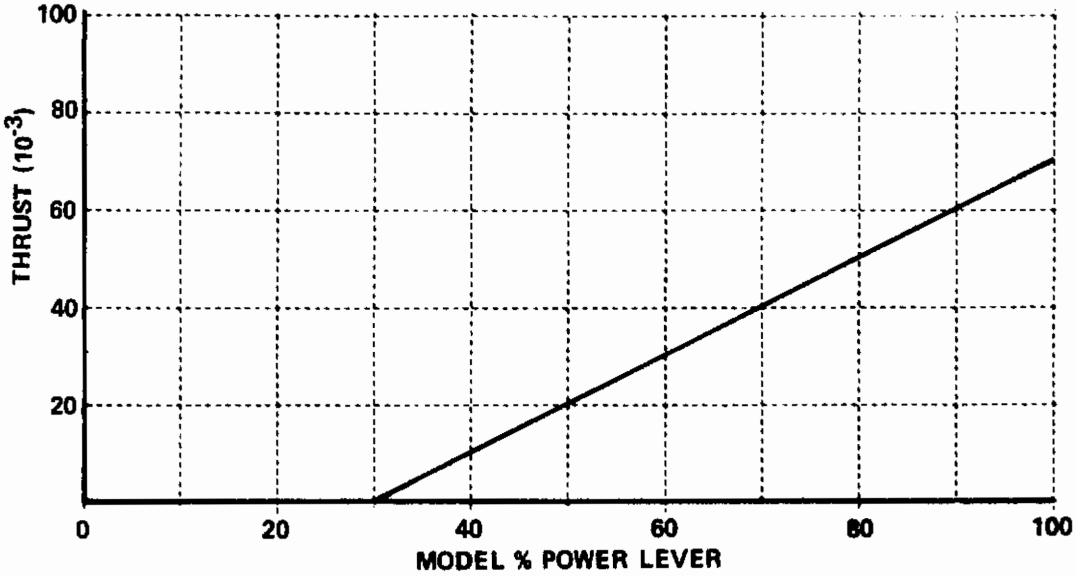


Figure I-1 STATIC THRUST MODEL

Although the maximum model thrust available was 70,000 lb, the simulation was not degraded since only the landing approach was simulated.

Actuator Dynamics

Hydraulic actuators were simulated using a first-order lag. Figure I-2 represents the elevator, aileron and rudder outputs to a unit step input.

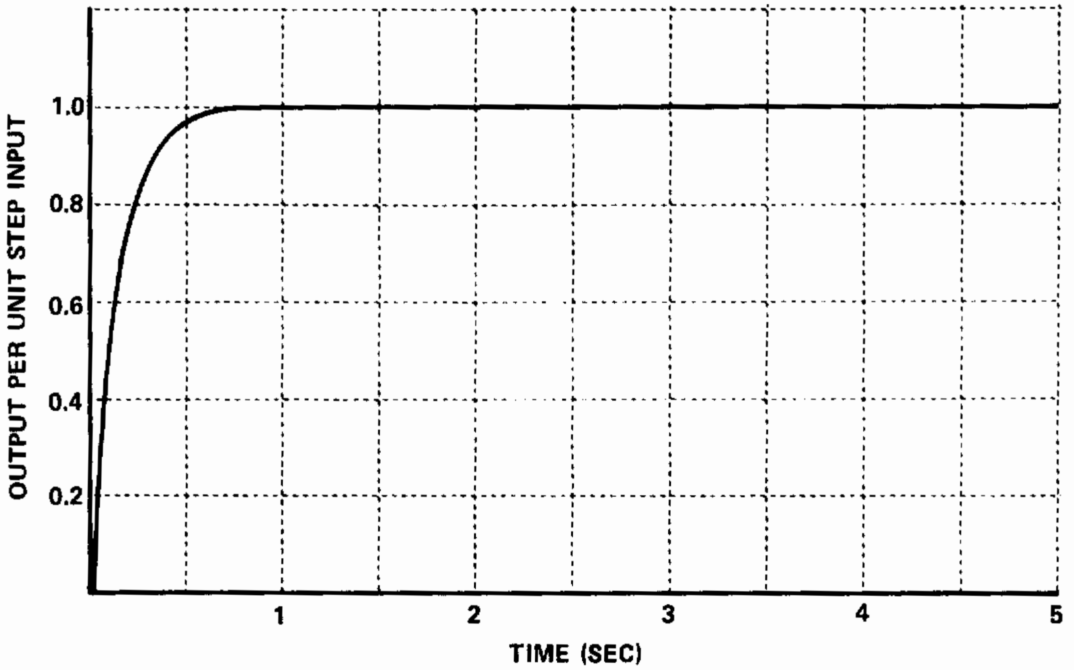


Figure I-2 SIMULATION OF HYDRAULIC ACTUATOR (FIRST ORDER LAG)

Conversion to Primed Notation

The model equations for yawing moment and rolling moment were converted to primed notation, eliminating multiplication by inertial terms. Since the model was programmed in nondimensional derivatives, the conversion results in defining nondimensional primed derivatives.

Rewriting the $\dot{r}$ and $\dot{p}$ equations from the previous development, including the effect of asymmetrical thrust

$$\dot{r} = \frac{I_{xz}}{I_{zz}}\dot{p} + \frac{57.3\bar{q}SbC_n}{I_{zz}} + \frac{57.3T_{\bar{y}}}{I_{zz}} \tag{10.1}$$

$$\dot{p} = \frac{I_{xz}}{I_{xx}}\dot{r} + \frac{57.3\bar{q}SbC_{\ell}}{I_{xx}} \tag{5.3}$$

Multiplying the $\dot{p}$ equation by $\frac{I_{xz}}{I_{zz}}$ and adding to the $\dot{r}$ equation results in

$$\dot{r}\left[1 - \frac{I_{xz}^{2}}{I_{x}I_{z}}\right] = \frac{57.3\bar{q}Sb}{I_{zz}}\left[C_{n_{ST}} + \frac{I_{xz}}{I_{xx}}\,C_{\ell_{ST}}\right] + \frac{57.3T_{\bar{y}}}{I_{zz}} \tag{10.2}$$

Define

$$\left[1 - \frac{I_{xz}^{2}}{I_{xx}I_{zz}}\right] = \frac{1}{K} \tag{10.3}$$

$$K\left[C_{n} + \frac{I_{xz}}{I_{xx}}\,C_{\ell}\right] = C_{n}' \tag{10.4}$$

The $\dot{r}$ equation, in "nondimensional primed" notation becomes

$$\dot{r} = \frac{57.3\bar{q}Sb}{I_{zz}}\left[C_{n}'\right] + \frac{57.3T_{\bar{y}}}{I_{zz}}K \tag{10.5}$$

In a similar manner, the $\dot{p}$ equation becomes

$$\dot{p} = \frac{57.3\bar{q}Sb}{I_{xx}}\left[C_{\ell}'\right] + \frac{57.3T_{\bar{y}}}{I_{zz}}K\left[\frac{I_{xz}}{I_{xx}}\right] \tag{10.6}$$

where $C_{\ell}' = K\left\{C_{\ell} + \frac{I_{xz}}{I_{zz}}C_{n}\right\}$

The above equations for $\dot{r}$ and $\dot{p}$ were mechanized on the model computer.

Appendix II

Axis Transformation of Model States
From Model c.g. to TIFS c.g.

Response variables of the model were computed in flight at the model cg. These parameters had to be transformed to the TIFS cg, since model following was about the TIFS center of gravity. The body axes of the model and TIFS were assumed to be parallel enabling only a linear (ℓ_x, ℓ_z) transformation to be used. The transformation distances were determined as follows; first the evaluation cockpit of TIFS and the model cockpit are assumed to be the same point in space, then from the distances between the evaluation cockpit and the TIFS cg and the distance between the model cockpit and the model cg the transformation distances are determined. The purpose of transforming model data to the TIFS cg from the model cg is based on the fact that the sensor data is determined at the TIFS cg. From the dynamics of rigid bodies, if the TIFS cg can be made to fly like that same point in space with respect to the model cg, then following is also achieved at the evaluation cockpit. The transformations used, neglecting high order terms, are

$$\dot{\alpha}_{I_{m_{TCG}}} = \dot{\alpha}_{I_m} - \frac{\dot{q}_{I_m}}{V_{I_m}} \ell_{x_{m_{TCG}}} \qquad (\ell_{x_{m_{TCG}}} = 22.5 \text{ ft.})$$

$$\alpha_{I_{m_{TCG}}} = \alpha_{I_m} - \frac{q_{I_m}}{V_{I_m}} \ell_{x_{m_{TCG}}}$$

$$\beta_{I_{m_{TCG}}} = \beta_{I_m} + \frac{r_{I_m} \ell_{x_{m_{TCG}}}}{V_{I_m}} - \frac{p_{I_m} \ell_{z_{m_{TCG}}}}{V_{I_m}} \qquad (\ell_{z_{m_{TCG}}} \ -8.75 \text{ ft.})$$

$$\dot{\beta}_{I_{m_{TCG}}} = \dot{\beta}_{I_m} + \frac{\dot{r}_{I_m} \ell_{x_{m_{TCG}}}}{V_{I_m}} - \frac{\dot{p}_{I_m} \ell_{z_{m_{TCG}}}}{V_{I_m}}$$

$$n_{y_{m_{TCG}}} = n_{y_m} + \frac{\dot{r}_{I_m} \ell_{x_{m_{TCG}}}}{V_{I_m}} - \frac{\dot{p}_{I_m} \ell_{z_{m_{TCG}}}}{V_{I_m}}$$

$$V_{I_{m_{TCG}}} = V_{I_m} + \frac{q_{I_m} \, l_{g m_{TCG}}}{57.3}$$

$$\dot{V}_{I_{m_{TCG}}} = \dot{V}_{I_m} + \frac{l_{g m_{TCG}} \, \dot{q}_{I_m}}{57.3}$$

A complete development of the above transformation is presented in Reference 14.

Appendix III
Data Recording

A 60 channel digital recording system was used for the acquisition of quantitative data. Two channels were used for "book keeping", such as record numbers and calibrations. The remaining 58 channels recorded model parameters, aircraft attitude data, control data and cockpit instrument data.

Model parameters recorded were:

$$\left.\begin{array}{l} \Delta\theta_m \\ \Delta\alpha_{I_{m_{TCG}}} \\ \Delta V_{I_{m_{TCG}}} \\ \Delta n_{z_{p_m}} \\ \Delta\delta_{e_m} \\ \Delta\delta_{a_m} \\ \Delta\delta_{r_m} \end{array}\right\} \text{incremental values from time of engage.}$$

$$\begin{array}{l} q_{I_m} \\ \dot{\alpha}_{I_{m_{TCG}}} \\ \dot{V}_{I_{m_{TCG}}} \\ \phi_m \\ p_{I_m} \\ r_{I_m} \\ \beta_{I_{m_{TCG}}} \\ \dot{\beta}_{I_{m_{TCG}}} \\ n_{y_{p_m}} \\ T_m \\ \sin\gamma_m \end{array}$$

$$\left.\begin{array}{l} \beta_{T_m} \\ \alpha_{T_m} \\ V_{T_m} \end{array}\right\} \text{Total model values, include gust terms.}$$

The following airplane (TIFS) data, incremental and total were recorded. Details of TIFS sensor signals are presented in Reference 4.

$$\left.\begin{array}{l} \Delta h \\ \Delta\theta \\ \Delta\alpha_I \\ \Delta\alpha_c \\ \Delta V \\ \Delta n_{z_p} \end{array}\right\} \text{incremental values from time of engage.}$$

$\sin \epsilon\psi$ $(\epsilon = \text{error})$

θ

q_I

α_I

$\dot{\alpha}_I$

V_I

$\dot{V}_I$

ϕ

p_I

r_I

β_I

$\dot{\beta}_I$

n_{y_p}

h_r

$\sin\gamma$

$\dot{h}$

$$\left.\begin{array}{l} \alpha_I + \alpha_g \\ \beta_I + \beta_g \end{array}\right\} \text{include gust terms}$$

The following (TIFS) control data were also recorded.

δ_a

δ_r

δ_e

δ_x^R

δ_y^R

δ_z^R

$$\left.\begin{array}{l} F_{AW} \\ F_{EW} \\ F_{RP} \end{array}\right\} \begin{array}{l}\text{Force inputs by} \\ \text{evaluation pilot}\end{array}$$

Instrument data recorded were

Horizontal steering pointer
Vertical steering pointer
ILS glide slope
ILS localizer

APPENDIX IV

DIGITAL RESPONSE TO AILERON AND RUDDER INPUTS

This appendix presents the primed dimensional stability derivatives and the control derivatives for each of the configurations evaluated (Table IV-I).

Table IV-II lists the configuration groups used in this appendix and referred to throughout the text.

Figures IV-1 through IV-8 present selected groups of digital responses to lagged aileron and lagged rudder inputs. The parameters shown: ϕ, p, β, r, and n_y were computed at the model center of gravity. The digital lag inputs are the same as the lag inputs programmed on the model analog computer. Lateral-directional modal parameters are given for the configurations presented.

Digital responses of lateral acceleration at the evaluation pilot station (n_{y_p}) to a lagged aileron step input are presented in Figure IV-9. All configurations are shown since evaluation pilots frequently commented on the lateral accelerations.

All digital responses were computed based on the lagged step command illustrated in Appendix I, Figure I-2.

Table IV-I

STABILITY DERIVATIVES FOR PHASE I

(BODY AXIS, PRIMED NOTATION)

CONF	Y_β	Y_p	Y_r	Y_{δ_a}	Y_{δ_r}	L'_β	L'_p	L'_r	L'_{δ_a}	L'_{δ_r}	N'_β	N'_p	N'_r	N'_{δ_a}	N'_{δ_r}	$\frac{N'_{\delta_a}}{L'_{\delta_a}}$
P-1	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7049	.0919	-1.0443	.1823	.4983	-.1040	-.1624	-.0368	-.2010	.0352
P-2	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7049	.0919	-1.0432	.1823	.4983	-.1040	-.1624	-.1174	-.2010	.1125
P-3	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7049	.0919	-1.0466	.1823	.4983	-.1040	-.1624	+.1244	-.2010	-.1189
P-4	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7049	.0919	-1.0416	.1823	.4983	-.1040	-.1624	-.2382	-.2010	.2287
P-6	-.0756	.00234	.0105	.00287	.0162	-1.2312	-2.7049	.0919	-1.0443	.1823	.5016	-.1040	-.1624	-.0368	-.2010	.0352
P-7	-.0756	.00234	.0105	.00287	.0162	-2.4571	-2.7049	.0919	-1.0443	.1823	.5057	-.1040	-.1624	-.0368	-.2010	.0352
P-8	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7019	.0919	-1.0443	.1823	.4983	-.3301	-.1624	-.0368	-.2010	.0352
P-9	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7111	.0919	-1.0443	.1823	.4983	+.3482	-.1624	-.0368	-.2010	.0352
P-12	-.0756	.00234	.0105	.00287	.0162	-1.2312	-2.7019	.0919	-1.0443	.1823	.5016	-.3301	-.1624	-.0368	-.2010	.0352
P-13	-.0756	.00234	.0105	.00287	.0162	-1.2312	-2.7111	.0919	-1.0443	.1823	.5016	+.3482	-.1624	-.0368	-.2010	.0352
P-14	-.0756	.00234	.0105	.00287	.0162	-1.2312	-2.7049	.0919	-1.0432	.1823	.5016	-.1040	-.1624	-.1174	-.2010	.1125
P-16	-.0756	.00234	.0105	.00287	.0162	-1.2312	-2.7049	.0919	-1.0416	.1823	.5016	-.1040	-.1624	-.2382	-.2010	.2287
S-1	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7049	1.8356	-1.0443	.1823	.4983	-.1040	-.1655	-.0368	-.2010	.0352
S-2	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7049	2.7523	-1.0443	.1823	.4983	-.1040	-.1686	-.0368	-.2010	.0352
S-3	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7049	1.8356	-1.0432	.1823	.4983	-.1040	-.1655	-.1174	-.2010	.1125
S-5	-.0756	.00234	.0105	.00287	.0162	-.25174	-2.7049	1.8356	-1.0416	.1823	.4983	-.1040	-.1655	-.2382	-.2010	.2287
S-7	-.0756	.00234	.0105	.00287	.0162	-1.2312	-2.7049	1.8356	-1.0432	.1823	.5016	-.1040	-.1655	-.1174	-.2010	.1125

TABLE IV-II

GROUPINGS OF CONFIGURATIONS

GROUP	CONFIGURATIONS
A. 1	P-1, P-2, P-3, P-4
A. 2	P-6, P-14, P-16
A. 3	S-1, S-3, S-5
B. 1	P-1, P-6, P-7
B. 6	S-3, S-7
C. 1	P-1, P-8, P-9
C. 2	P-6, P-12, P-13
D. 1	P-1, S-1, S-2

GROUP A.1

VARIATION OF $C_{n_{\delta_a}}$ ABOUT BASELINE

CONFIG.	$N'_{\delta_a}/L'_{\delta_a}$	P.R.	T.R.	TURBULENCE DESCRIPTION	PILOT	ζ_ϕ	ω_ϕ	FLT #
P-1	.0352	5	–	MODERATE	A	.1892	.7192	86
P-1	.0352	3	C	LIGHT/MOD.	A	.1892	.7192	90
P-1	.0352	5-5½	B	——	B	.1892	.7192	96
P-1	.0352	3	–	——	C	.1892	.7192	98
P-2	.1125	5	D	LIGHT	A	.225	.7371	88
P-2	.1125	5-5½	B	——	B	.225	.7371	96
P-2	.1125	2	A	——	C	.225	.7371	98
P-3	-.1189	9-10	–	LIGHT	A	.1136	.6822	90
P-3	-.1189	9	–	——	C	.1136	.6822	98
P-4	.2287	6	D	LIGHT	A	.2765	.7638	112
P-4	.2287	6	A	LIGHT	C	.2765	.7638	99

LATERAL-DIRECTIONAL MODAL PARAMETERS FOR GROUP A.1

ω_d - rad/sec	.7445
ζ_d	.1965
τ_R - sec	.373
T_{2_s} - sec	21.4
$\lvert \phi/\beta \rvert_d$	.299
$\measuredangle \phi/\beta_d$ - deg	127.9

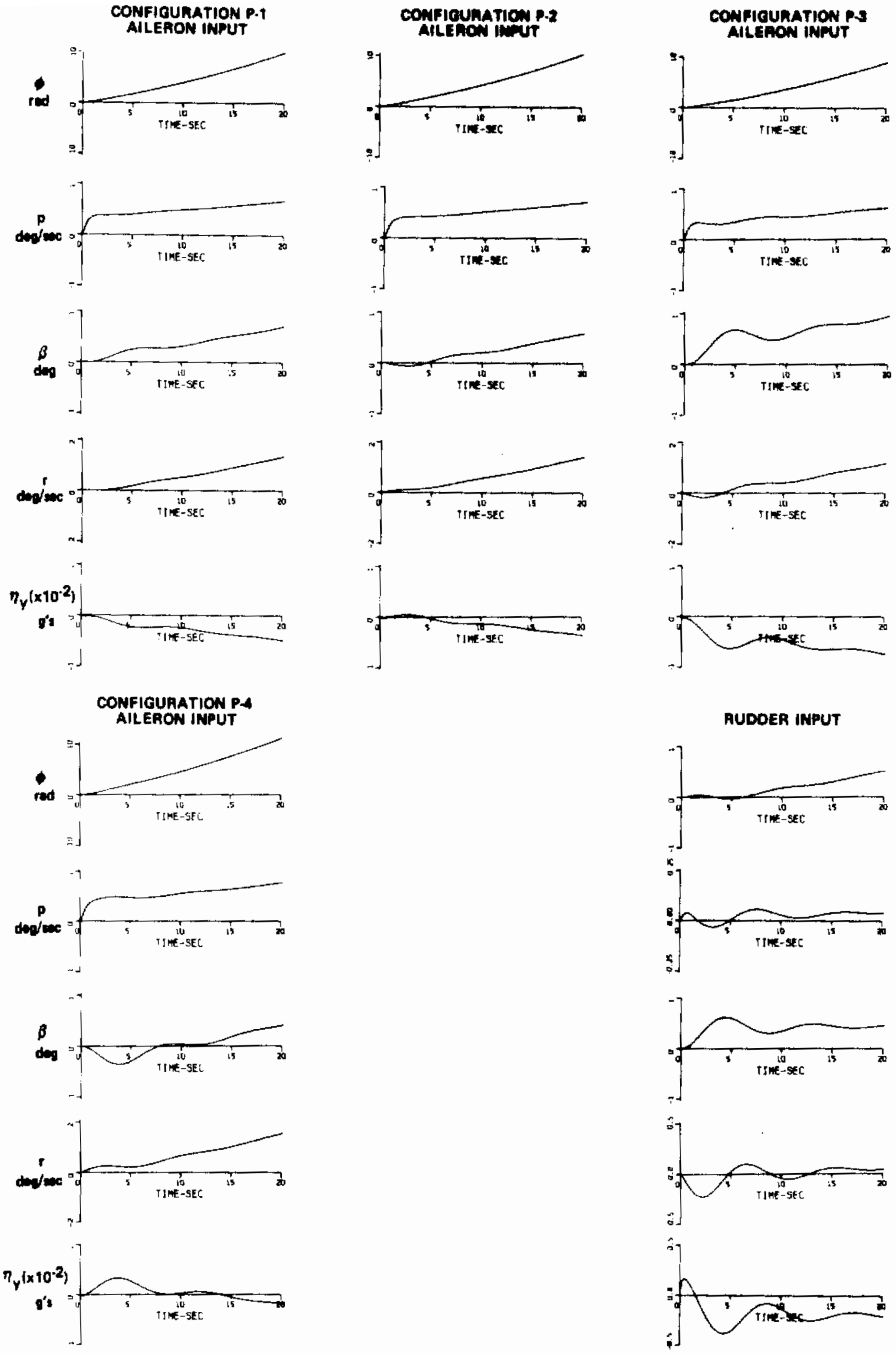


Figure IV-1 (GROUP A.1)

GROUP A.2

VARIATION OF $C_{n_{\delta_a}}$ ABOUT BASELINE WITH C_{ℓ_β} = 5 BL

CONFIG.	$N'_{\delta_a}/L'_{\delta_a}$	P.R.	T.R.	TURBULENCE DESCRIPTION	PILOT	ζ_ϕ	ω_ϕ	FLT #
P-6	.0352	4	D-E	MODERATE	A	.1844	.7450	87
P-14	.1125	7	E	MODERATE	A	.2063	.8105	87
P-14	.1125	2½	A	NONE	C	.2063	.8105	100
P-16	.2287	7	D	LIGHT	A	.2359	.9012	115

LATERAL-DIRECTIONAL MODAL PARAMETERS FOR GROUP A.2

ω_d - rad/sec	.7937
ζ_d	.1513
τ_R - sec	.366
T_{2_S} - sec	48.3
$\lvert\phi/\beta\rvert_d$	.624
$\measuredangle\, \phi/\beta_d$ - deg	88.04

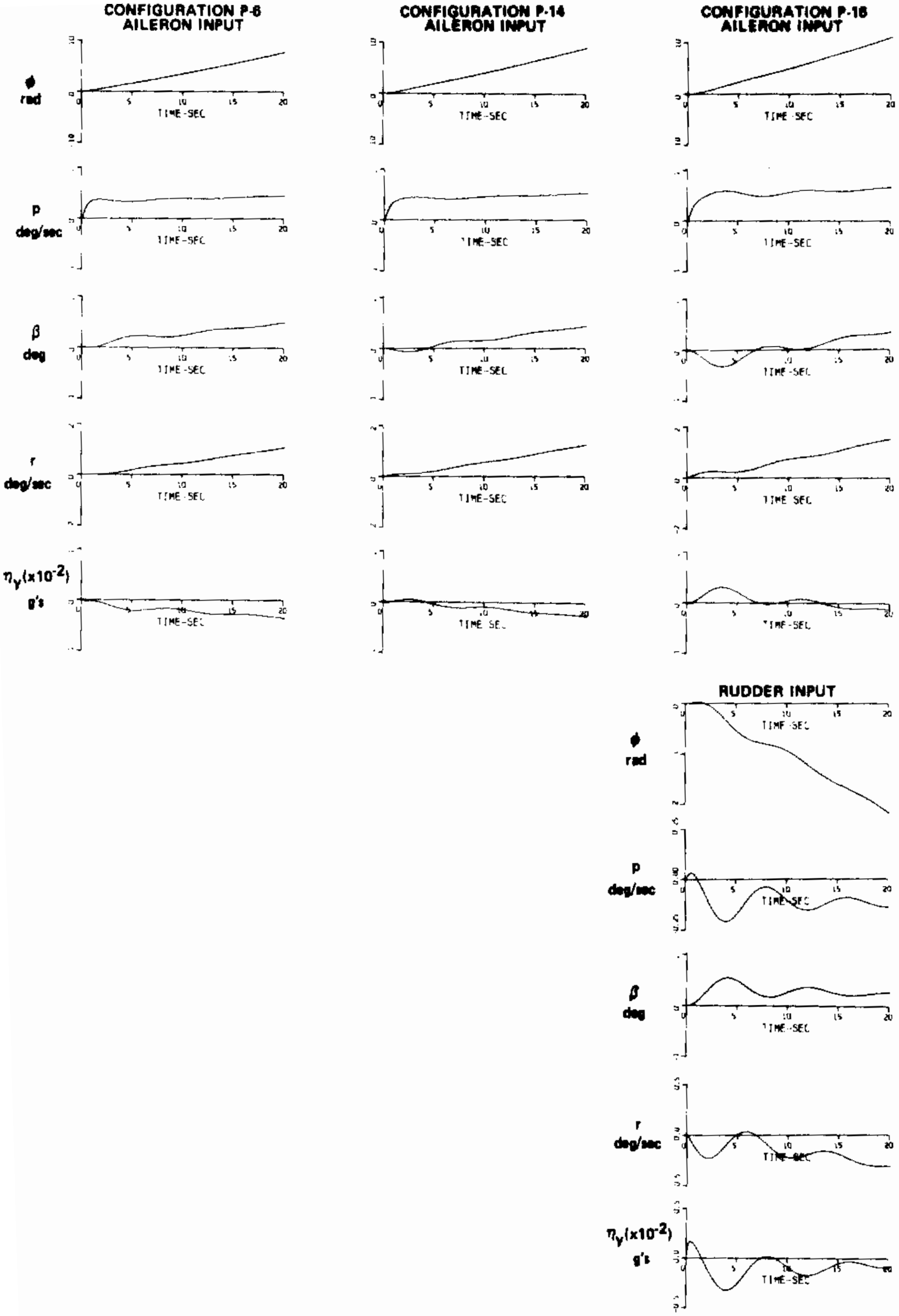


Figure IV-2 (GROUP A.2)

GROUP A.3

VARIATION OF $C_{n_{\delta_a}}$ ABOUT BASELINE WITH C_{l_r} = 2 BL

CONFIG.	$N'_{\delta_a}/L'_{\delta_a}$	P.R.	T.R.	TURBULENCE DESCRIPTION	PILOT	ζ_ϕ	ω_ϕ	FLT #
S-1	.0352	7	D	LIGHT/MOD.	A	.2136	.7201	89
S-1	.0352	5	D	LIGHT	A	.2136	.7201	112
S-1	.0352	7	D	––	B	.2136	.7201	94
S-3	.1125	5	B	LIGHT	A	.2957	.7417	114
S-5	.2287	7	D	LIGHT/MOD.	A	.4125	.7736	115

LATERAL-DIRECTIONAL MODAL PARAMETERS FOR GROUP A.3

ω_d - rad/sec	.7690
ζ_d	.2390
τ_R - sec	.377
T_{2_S} - sec	9.6
$\lvert \phi/\beta \rvert_d$	.589
$\measuredangle\, \phi/\beta_d$ - deg	139.6

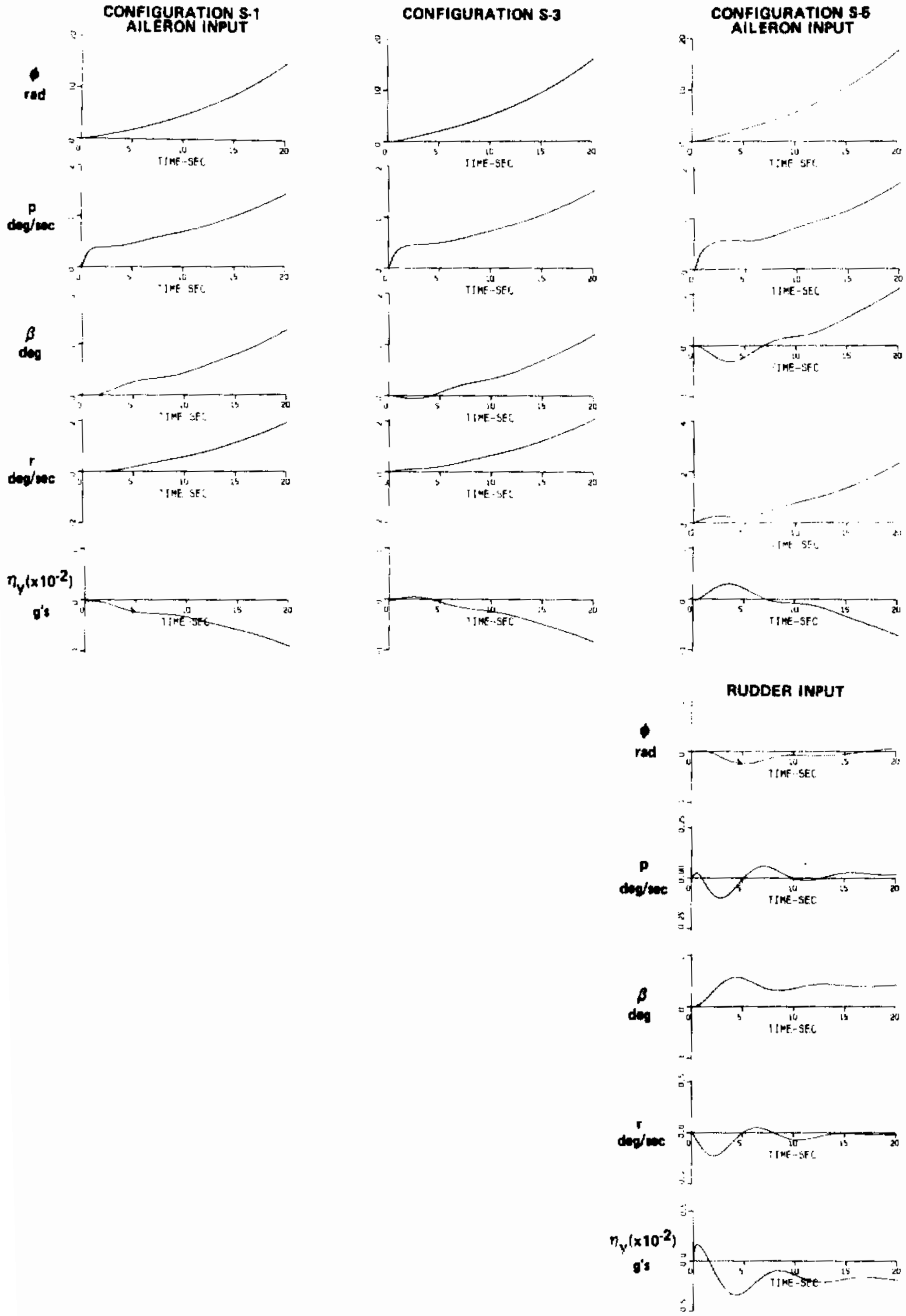


Figure IV-3 (GROUP A.3)

GROUP B.1

VARIATION OF C_{ℓ_β} WITH BASELINE $C_{n_{\delta_a}}$

CONFIG.	L'_β	P.R.	T.R.	TURBULENCE DESCRIPTION	PILOT	ζ_ϕ	ω_ϕ	FLT #
P-1	-.25174	5	–	MODERATE	A	.1892	.7191	86
P-1	-.25174	3	C	LIGHT/MOD.	A	.1892	.7191	90
P-1	-.25174	5-5½	B	---	B	.1892	.7191	96
P-1	-.25174	3	–	---	C	.1892	.7191	98
P-6	-1.2312	4	D-E	MODERATE	A	.1844	.7450	87
P-7	-2.4571	5	C	VERY LIGHT	A	.1792	.7762	113
P-7	-2.4571	3½	A	---	B	.1792	.7762	95

LATERAL-DIRECTIONAL MODAL PARAMETERS FOR GROUP B.1

CONFIGURATION	P-1	P-6	P-7
ω_d - rad/sec	.7445	.7937	.8522
ζ_d	.1965	.1513	.1070
τ_R - sec	.373	.368	.362
T_{2_S} - sec	21.4	48.3	40.0*
$\lvert \phi/\beta \rvert_d$	.299	.624	1.072
$\measuredangle \phi/\beta_d$ - deg	127.9	88.04	78.24

*τ_S - sec = 40.0

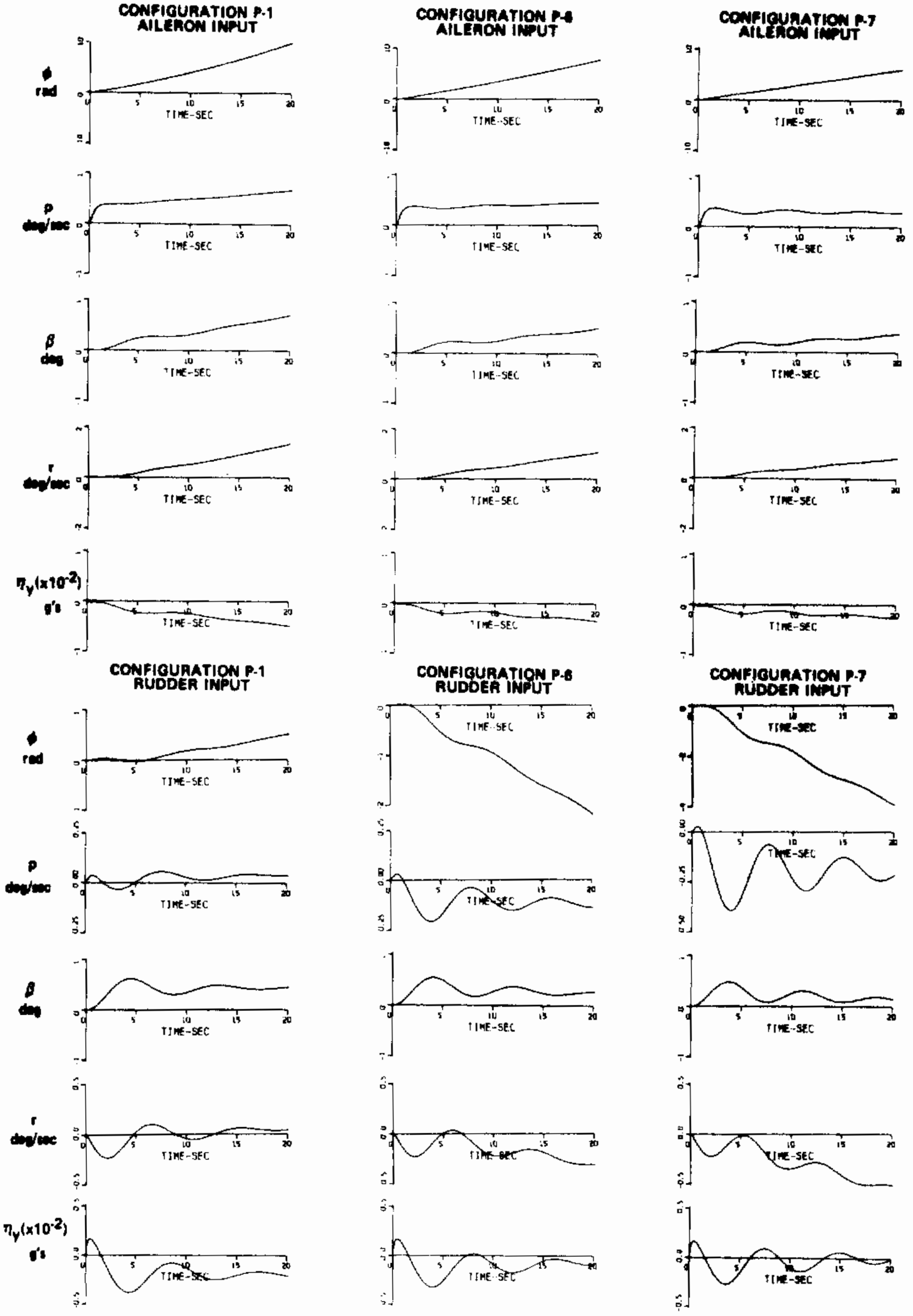


Figure IV-4 (GROUP B.1)

GROUP B.6

VARIATION OF C_{l_β} ABOUT BASELINE WITH C_{l_r} = 5 BL AND $C_{n_{\delta_a}}$ = 3 BL

CONFIG.	L'_β	P.R.	T.R.	TURBULENCE DESCRIPTION	PILOT	ζ_ϕ	ω_ϕ	FLT #
S-3	-.25174	5	B	LIGHT	A	.2957	.7417	114
S-7	-1.2312	6	E-F	LIGHT/MOD.	A	.2709	.8147	91
S-7	-1.2312	2	B	LIGHT/MOD.	C	.2709	.8147	100

LATERAL-DIRECTIONAL MODAL PARAMETERS FOR GROUP B.6

CONFIGURATION	S-3	S-7
ω_d - rad/sec	.7690	.8140
ζ_d	.2390	.1906
τ_R - sec	.378	.372
T_{2_S} - sec	9.56	13.65
$\lvert \phi/\beta \rvert_d$	.589	.766
$\measuredangle \phi/\beta_d$ - deg	139.6	106.6

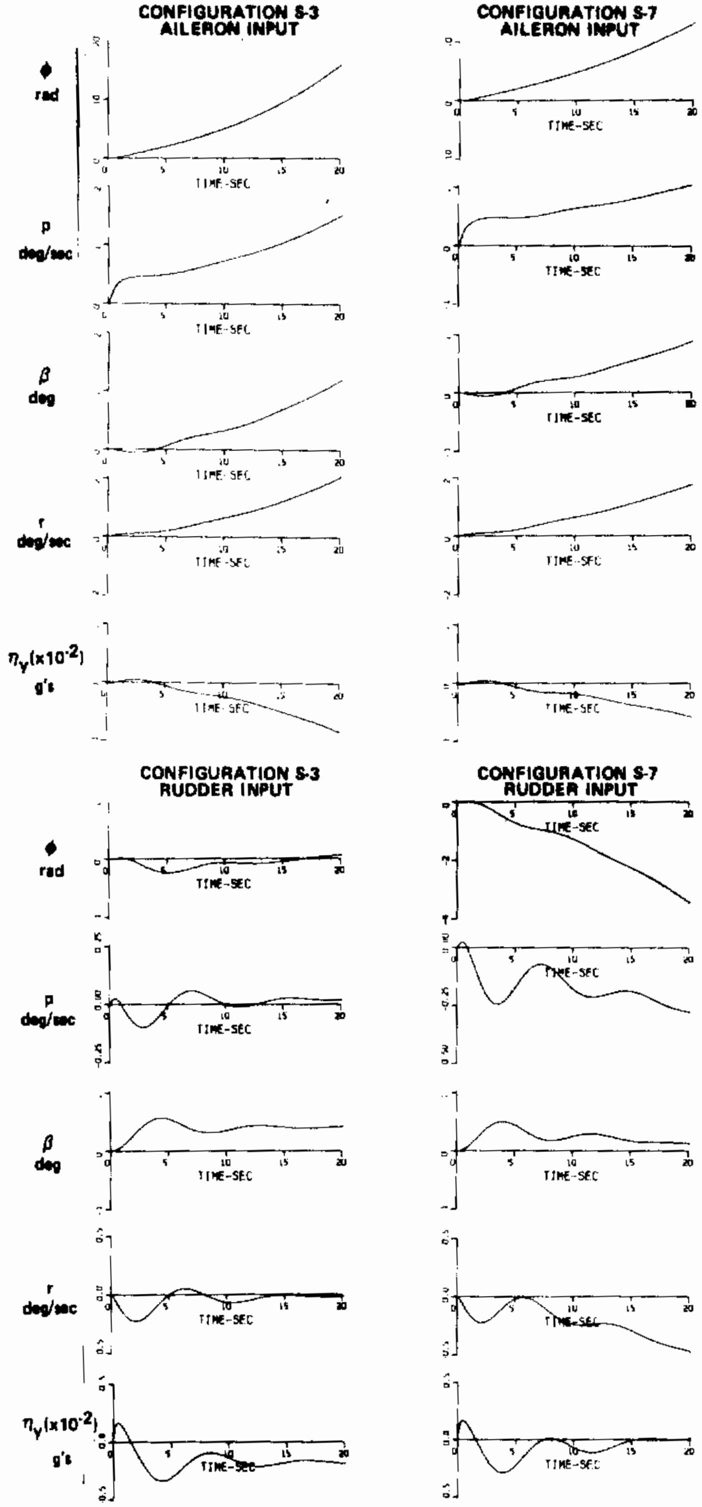


Figure IV-5 (GROUP B.6)

GROUP C.1

VARIATION OF C_{n_p} ABOUT BASELINE

CONFIG.	N'_p	P.R.	T.R.	TURBULENCE DESCRIPTION	PILOT	ζ_ϕ	ω_ϕ	FLT #
P-1	-.1040	5	—	MODERATE	A	.1892	.7191	86
P-1	-.1040	3	C	LIGHT/MOD.	A	.1892	.7191	90
P-1	-.1040	5-5½	B	——	B	.1892	.7191	96
P-1	-.1040	3	—	——	C	.1892	.7191	98
P-8	-.3301	8	C	LIGHT	A	.1887	.7198	89
P-8	-.3301	9-10	A-B	——	B	.1887	.7198	93
P-8	-.3301	6-6½	A-B	——	C	.1887	.7198	101
P-9	+.3482	9	D	LIGHT	A	.1703	.7176	113
P-9	+.3482	8-9	D	LIGHT/MOD.	B	.1703	.7176	94
P-9	+.3482	4½	B-C	LIGHT/MOD.	C	.1703	.7176	99

LATERAL-DIRECTIONAL MODAL PARAMETERS FOR GROUP C.1

CONFIGURATION	P-1	P-8	P-9
ω_d - rad/sec	.7445	.7735	.6884
ζ_d	.1965	.2335	.1196
τ_R - sec	.373	.383	.355
T_{2_S} - sec	21.4	22.8	18.9
$\lvert \phi/\beta \rvert_d$	.299	.295	.308
$\measuredangle \phi/\beta_d$ - deg	127.9	128.1	127.8

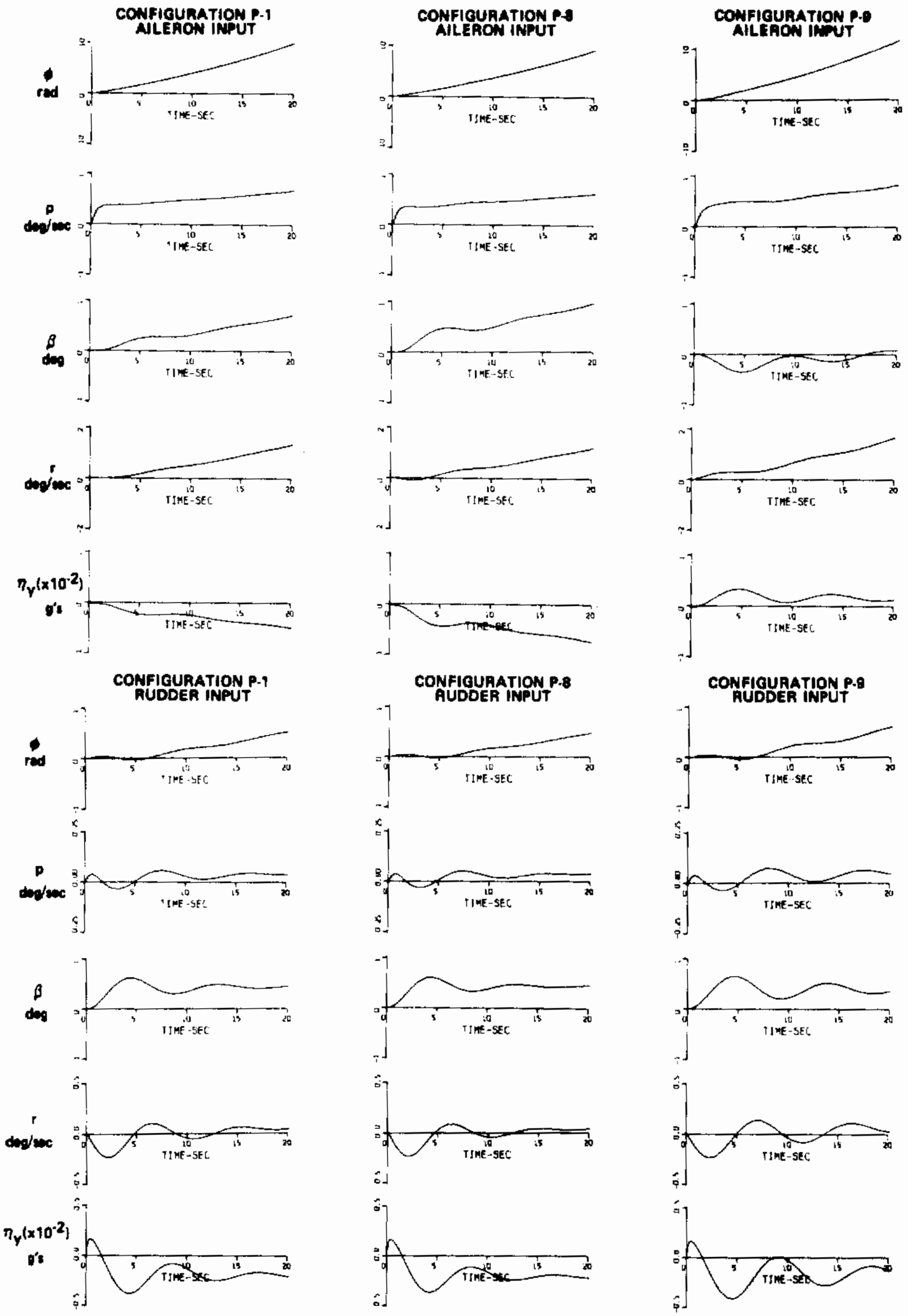


Figure IV-6 (GROUP C.1)

GROUP C.2

VARIATION OF C_{n_p} ABOUT BASELINE WITH C_{l_β} = 5 BL

CONFIG.	N'_p	P.R.	T.R.	TURBULENCE DESCRIPTION	PILOT	ζ_ϕ	ω_ϕ	FLT #
P-6	-.1040	4	D-E	MODERATE	A	.1844	.7450	87
P-12	-.3301	7	F	LIGHT/MOD.	A	.1936	.7457	91
P-12	-.3301	5	B-C	LIGHT/MOD.	C	.1936	.7457	101
P-13	+.3482	6	D	LIGHT	A	.1662	.7435	114
P-13	+.3482	7	A	––	B	.1662	.7435	95

LATERAL-DIRECTIONAL MODAL PARAMETERS FOR GROUP C.2

CONFIGURATION	P-6	P-12	P-13
ω_d - rad/sec	.7937	.8642	.6377
ζ_d	.1513	.1584	.1392
τ_R - sec	.368	.374	.357
T_{2_S} - sec	48.3	62.7	26.7
$\left\| \phi/\beta \right\|_d$	.624	.581	.755
$\measuredangle \phi/\beta_d$ - deg	88.0	88.5	86.5

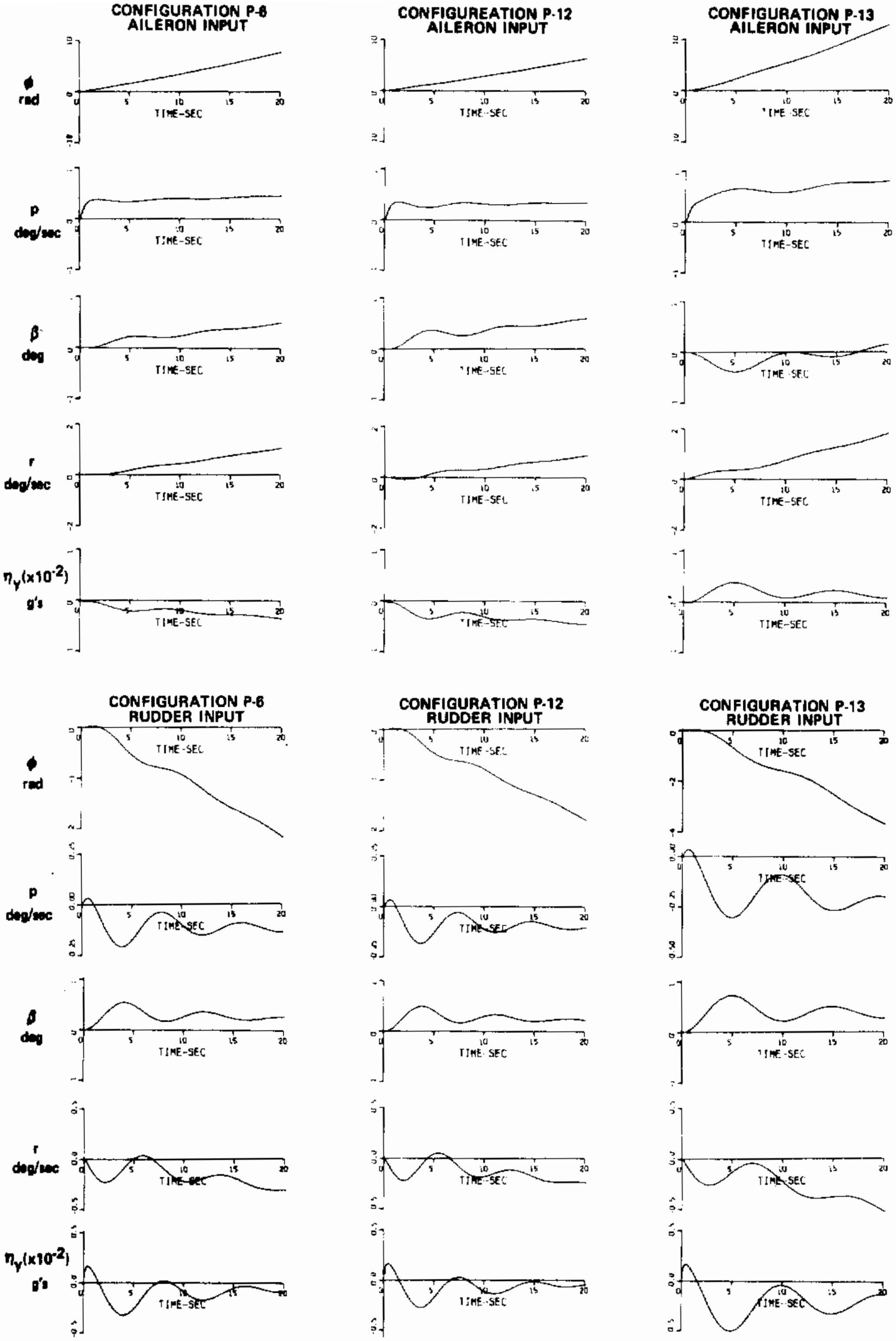


Figure IV-7 (GROUP C.2)

GROUP D.1

VARIATION OF ℓ_r ABOUT BASELINE

CONFIG.	L_r	P.R.	T.R.	TURBULENCE DESCRIPTION	PILOT	ζ_ϕ	ω_ϕ	FLT. #
P-1	.0919	5	–	MODERATE	A	.1892	.7191	86
P-1	.0919	3	C	LIGHT/MOD.	A	.1892	.7191	90
P-1	.0919	5-5½	B	––	B	.1892	.7191	96
P-1	.0919	3	–	––	C	.1892	.7191	98
S-1	1.8356	7	D	LIGHT/MOD.	A	.2136	.7201	89
S-1	1.8356	5	D	LIGHT	A	.2136	.7201	112
S-1	1.8356	7	D	––	B	.2136	.7201	94
S-2	2.7523	4	D	LIGHT/MOD.	A	.2379	.7211	88
S-2	2.7523	4-5	A	––	B	.2379	.7211	93

LATERAL-DIRECTIONAL MODAL PARAMETERS FOR GROUP D.1

CONFIGURATION	P-1	S-1	S-2
ω_d - rad/sec	.7445	.7690	.7957
ζ_d	.1965	.2390	.2756
τ_R - sec	.373	.377	.382
T_{2_S} - sec	21.4	9.6	6.4
$\|\phi/\beta\|_d$	.299	.589	.872
$\measuredangle \phi/\beta_d$ - deg	127.9	139.6	141.8

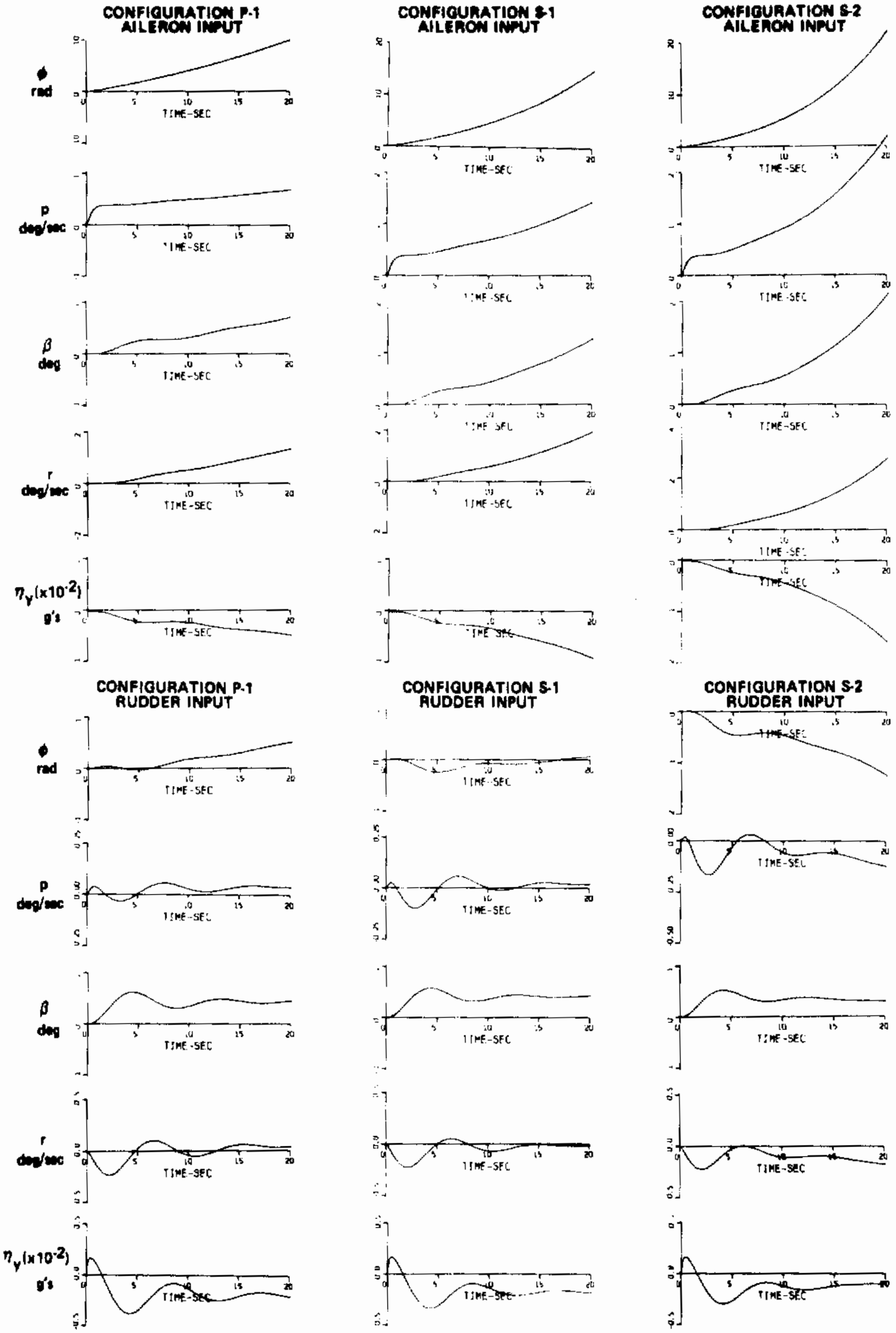


Figure IV-8 (GROUP D.1)

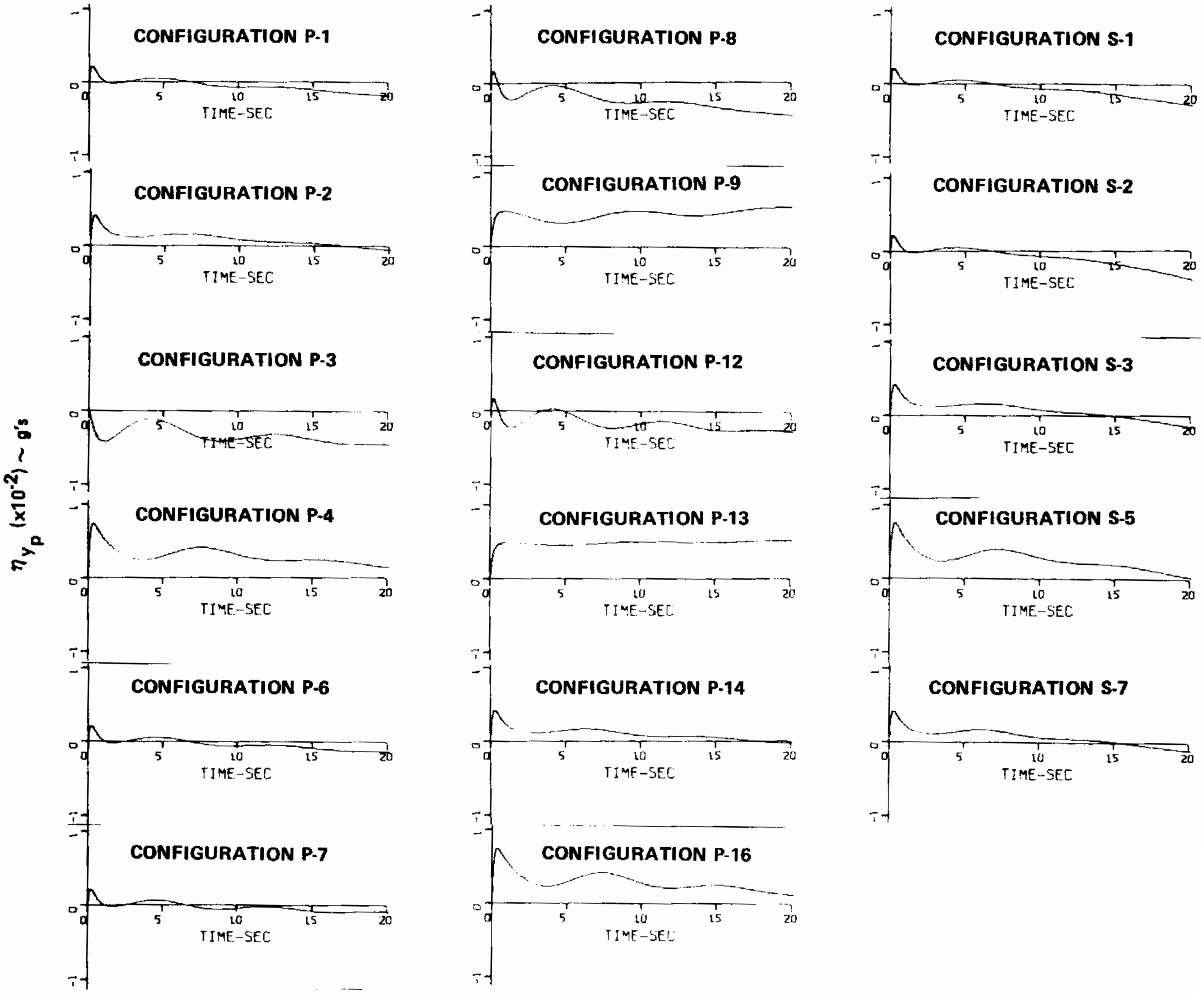


Figure IV-9 LATERAL ACCELERATION AT MODEL PILOT'S STATION TO AN AILERON STEP

TABLE IV-III

TRANSFER FUNCTION NUMERATORS (EVALUATED IN BODY AXES, AT MODEL C.G.)

PARAMETER	CONFIGURATIONS																
	P-1	P-2	P-3	P-4	P-6	P-7	P-8	P-9	P-12	P-13	P-14	P-16	S-1	S-2	S-3	S-5	S-7
$\phi/\delta_a = A_\phi(s^2+2\zeta_\phi\omega_\phi s+\omega_\phi^2)$																	
A_ϕ	-1.042	-1.036	-1.064	-1.027	-1.042	-1.042	-1.042	-1.042	-1.042	-1.042	-1.036	-1.027	-1.042	-1.042	-1.036	-1.027	-1.036
ζ_ϕ	.1882	.2250	.1136	.2765	.1844	.1792	.1986	.1703	.1935	.1662	.2063	.2359	.2136	.2378	.2967	.4125	.2708
ω_ϕ	.7191	.7371	.6822	.7638	.7450	.7762	.7198	.7176	.7457	.7436	.8105	.9011	.7200	.7210	.7417	.7735	.8147
$r/\delta_a = A_r(s+\frac{1}{T_{r_1}})\underbrace{(s+\frac{1}{T_{r_2}})(s+\frac{1}{T_{r_3}})}_{(s^2+2\zeta_r\omega_r s+\omega_r^2)}$ or																	
A_r	-.0368	-.1174	+.1244	-.2382	-.0368	-.0368	-.0368	-.0368	-.0368	-.0368	-.1174	-.2382	-.0368	-.0368	-.1174	-.2382	-.1174
$1/T_{r_1}$	-1.263	-1.980	.3379	-2.325	-1.296	-1.336	6.694	-12.59	6.696	-12.59	-2.015	-2.354	-12.63	-1.263	-1.980	-2.325	-2.015
$1/T_{r_2}(\zeta_r)$	(-.5750)	(-.1167)	-.4764	(-.0070)	(-.5748)	(-.5746)	.5279	(.0584)	.5475	(.0569)	(-.1343)	(-.0369)	(-.5750)	(-.5750)	(-.1167)	(-.0070)	(-.1343)
$1/T_{r_3}(\omega_r)$	(1.282)	(.5837)	-3.529	(.3881)	(1.312)	(1.347)	-.5874	(.4061)	-.6084	(.4209)	(.6379)	(.4579)	(1.282)	(1.282)	(.5837)	(.3881)	(.6379)
$\beta/\delta_a = A_\beta(s+\frac{1}{T_{\beta_1}})\underbrace{(s+\frac{1}{T_{\beta_2}})(s+\frac{1}{T_{\beta_3}})}_{(s^2+\zeta_\beta\omega_\beta s+\omega_\beta^2)}$ or																	
A_β	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029	.0029
$1/T_{\beta_1}$	2.809	.3543	42.46	-1.695	2.809	2.809	5.807	.0803	5.807	.0803	.3543	-1.695	2.827	2.845	.4471	-1.772	.4471
$1/T_{\beta_2}(\zeta_\beta)$	-20.49	-45.12	-4.822	-85.63	-20.49	-20.49	-23.58	(.8583)	-23.58	(.8583)	-45.12	-85.63	-20.48	-20.47	-45.11	-85.63	-45.11
$1/T_{\beta_3}(\omega_\beta)$	-.1777	-.8295	-.0203	.1227	-.1777	-.1777	-.0799	(10.45)	-.0799	(10.45)	-.8295	-.1227	-.2086	-.2391	-.9329	.1907	-.9329
$\phi/\delta_r = A_\phi\underbrace{(s+\frac{1}{T_{\phi_1}})(s+\frac{1}{T_{\phi_2}})}_{(s^2+2\zeta_\phi\omega_\phi s+\omega_\phi^2)}$ or																	
A_ϕ	.1946	→	→	→	.1946	.1946	.1946	.1946	.1946	.1946	.1946	→	.1946	.1946	.1946	→	.1946
$1/T_{\phi_1}(\zeta_\phi)$	(-.6583)	→	→	→	1.290	1.871	(-.6434)	(-.6815)	1.282	1.307	1.290	→	1.404	2.407	1.404	→	2.028
$1/T_{\phi_2}(\omega_\phi)$	(.4309)	→	→	→	-.6404	-1.119	(.4317)	(.4293)	-.6449	-.6316	-.6404	→	.1058	.0495	.1066	→	-.4257
$r/\delta_p = A_r(s+\frac{1}{T_{r_1}})\underbrace{(s+\frac{1}{T_{r_2}})(s+\frac{1}{T_{r_3}})}_{(s^2+2\zeta_p\omega_r s+\omega_r^2)}$ or																	
A_r	-.2010	→	→	→	-.2010	-.2010	-.2010	-.2010	-.2010	-.2010	-.2010	→	-.2010	-.2010	-.2010	→	-.2010
$1/T_{r_1}$	.0835	→	→	→	-2.818	-2.846	.0798	.0922	-3.022	-2.408	-2.818	→	.0835	.0351	.0835	→	-2.818
$1/T_{r_2}(\zeta_r)$	-.1237	→	→	→	(.0419)	(-.0185)	-.1207	-.1308	(.0386)	(.0524)	(.0419)	→	-.1237	-.1237	-.1237	→	(.0419)
$1/T_{r_3}(\omega_r)$	-2.794	→	→	→	(.1993)	(.3181)	-2.966	-2.392	(.1924)	(.2156)	(.1993)	→	-2.794	-2.794	-2.794	→	(.1993)
$\beta/\delta_r = A_\beta(s+\frac{1}{T_{\beta_1}})\underbrace{(s+\frac{1}{T_{\beta_2}})(s+\frac{1}{T_{\beta_2}})}_{(s^2+2\zeta_\beta\omega_\beta s+\omega_\beta^2)}$ or																	
A_β	.0162	→	→	→	.0162	.0162	.0162	.0162	.0162	.0162	.0162	.0162	.0162	.0162	.0162	.0162	.0162
$1/T_{\beta_1}$	-3.092	→	→	→	-3.092	-3.092	-3.403	-2.531	-3.403	-2.531	-3.092	-3.092	-3.169	-3.244	-3.169	-3.169	-3.169
$1/T_{\beta_2}(\zeta_\beta)$	-11.98	→	→	→	-11.98	-11.98	-11.67	-12.56	-11.67	-12.56	-11.98	-11.98	-11.95	-11.92	-11.95	-11.95	-11.95
$1/T_{\beta_3}(\omega_\beta)$	.0289	→	→	→	.0289	.0289	.0264	.0351	.0264	.0351	.0289	.0289	.0713	.1121	.0713	.0713	.0713

NOTE: NEGATIVE REAL ROOTS ARE IN LEFT HALF PLANE.

APPENDIX V

TYPICAL MODEL-FOLLOWING RESPONSES:

CLASSICAL INPUTS

LANDING APPROACH

The degree of model following to classical rudder and aileron steps is shown in Figures V-1 - V-5. The records were chosen to span the flights in the Phase I experiment.

Model following to a classical elevator step input is shown in Figure V- 6 . The longitudinal model did not vary throughout the experiment. The record shown was from a flight midway through the experiment.

Three IFR approach records are presented in Figures V-7 - V-9. These records are of the same configuration on three different flights and three different evaluation pilots. Each record is from an altitude of about 1000 feet to 250 feet or 70 seconds.

There was no degradation of model following throughout the experiment. The degree of model following shown is typical of any flight in the Phase I experiment.

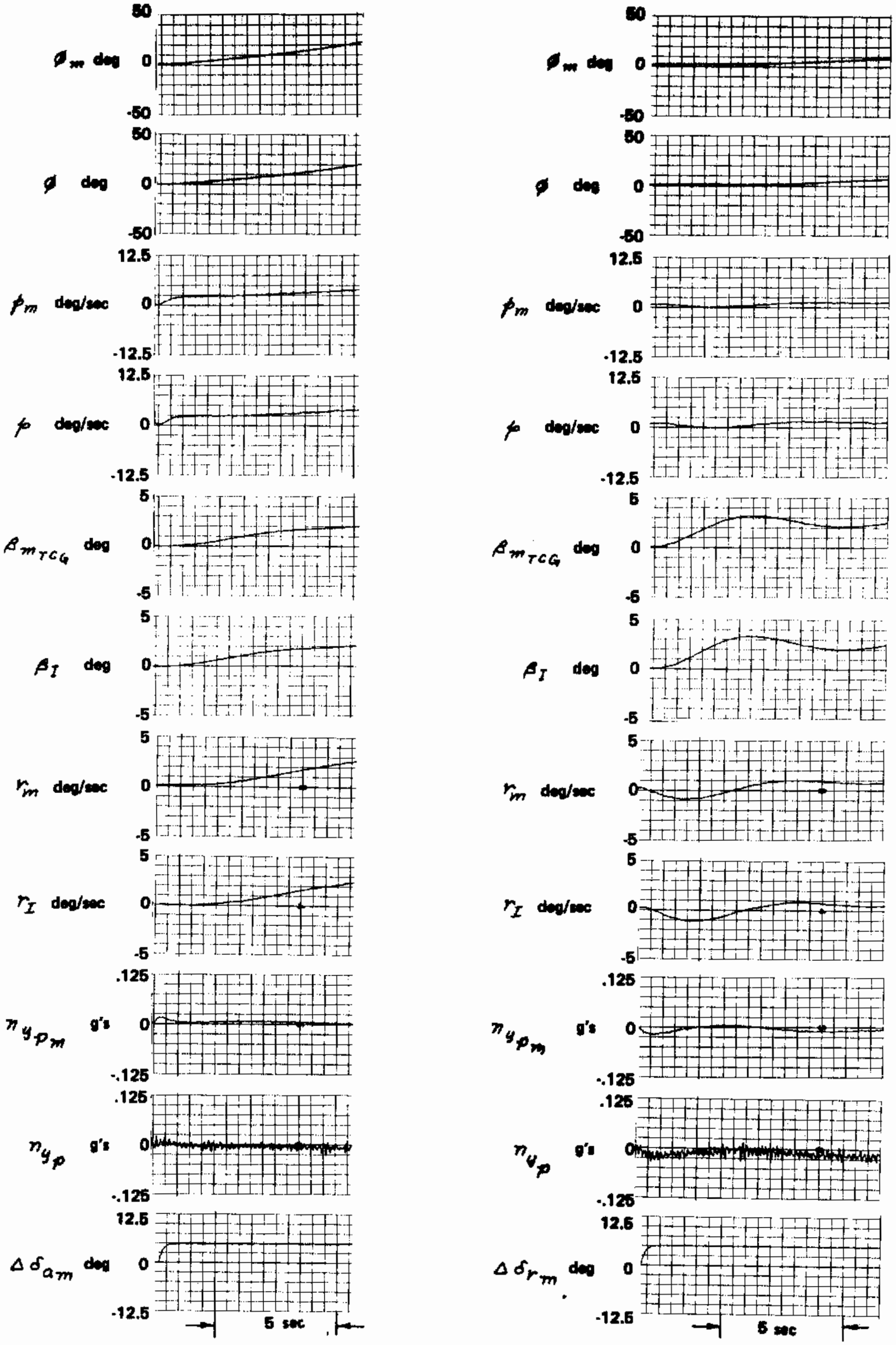


Figure V-1 Model Following Responses to Automatic Aileron and Rudder Step Inputs, Configuration S-1, Flight 112

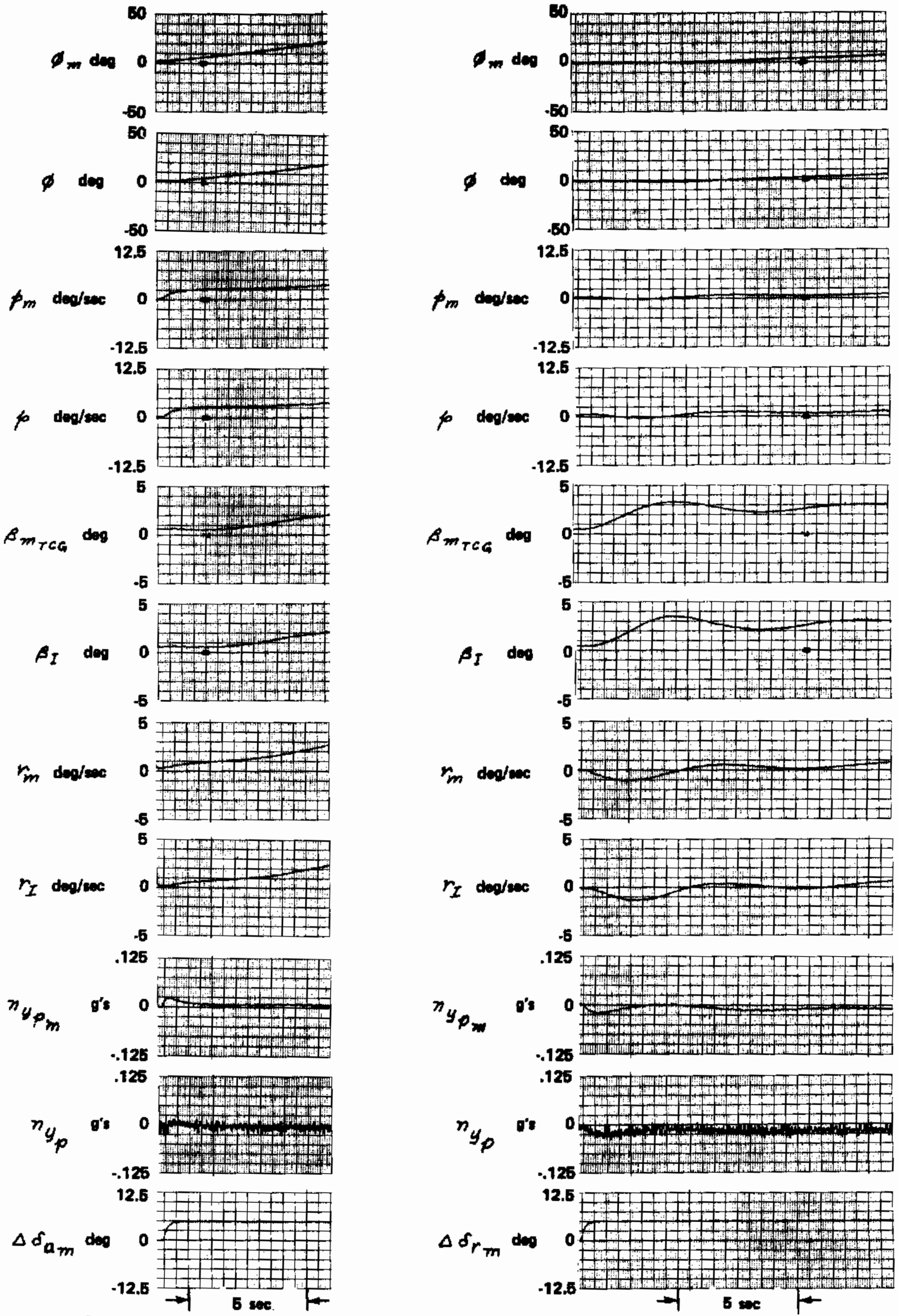


Figure V-2 Model Following Responses to Automatic Aileron and Rudder Step Inputs, Configuration S-3, Flight 114

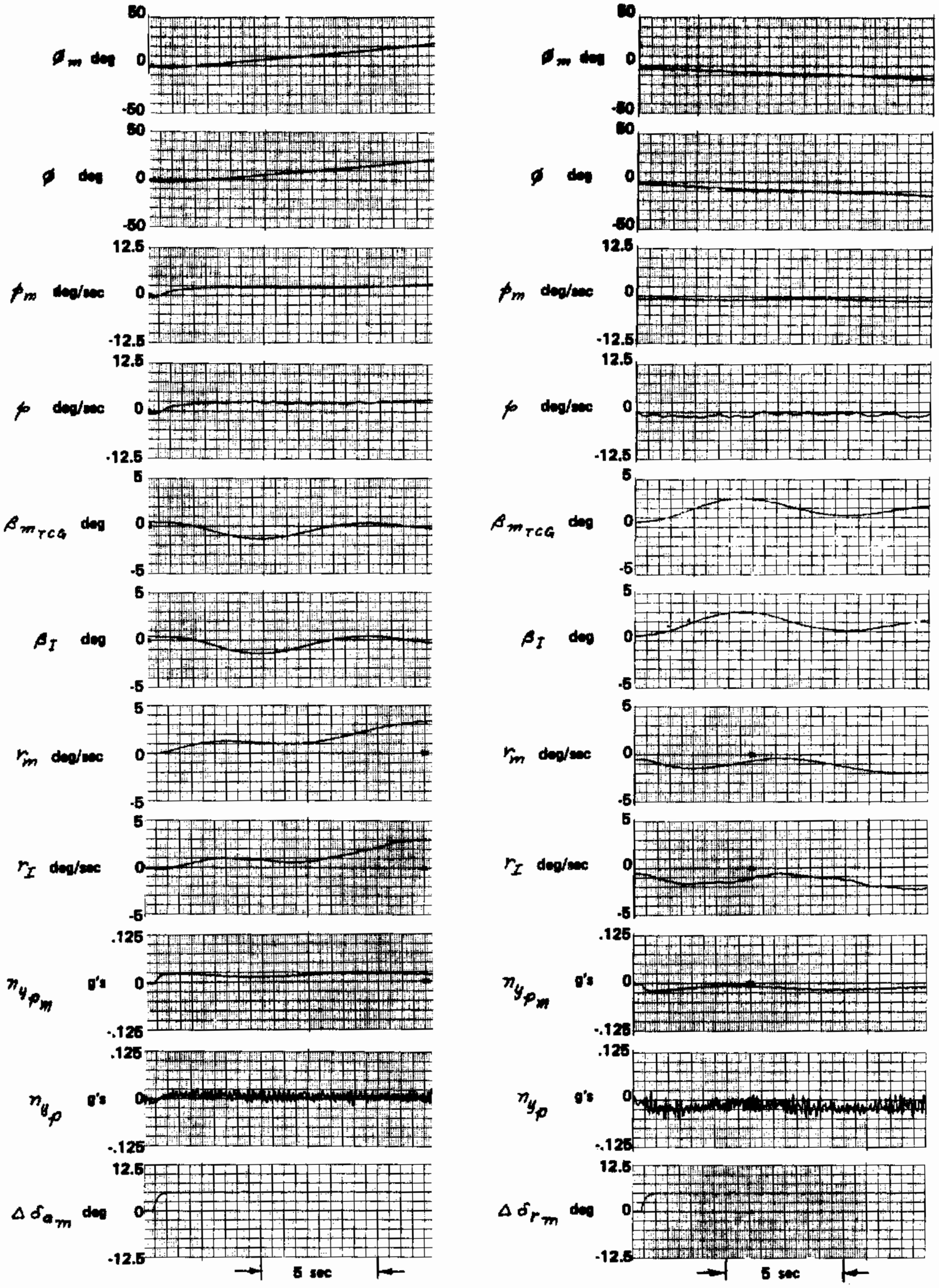


Figure V-3 Model Following Responses to Automatic Aileron and Rudder Step Inputs, Configuration P-9, Flight 99

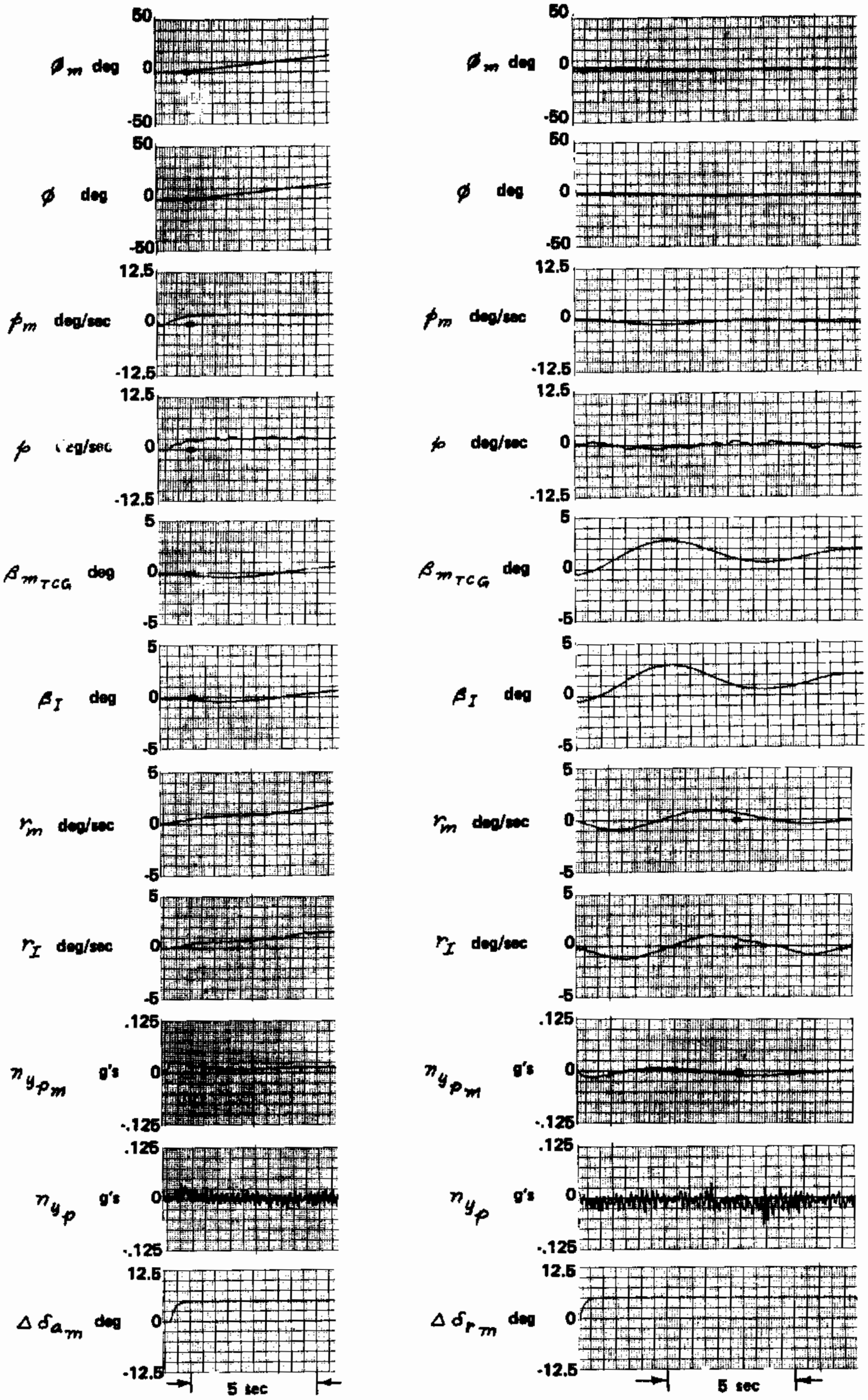


Figure V-4 Model Following Responses to Automatic Aileron and Rudder Step Inputs, Configuration P-14, Flight 87

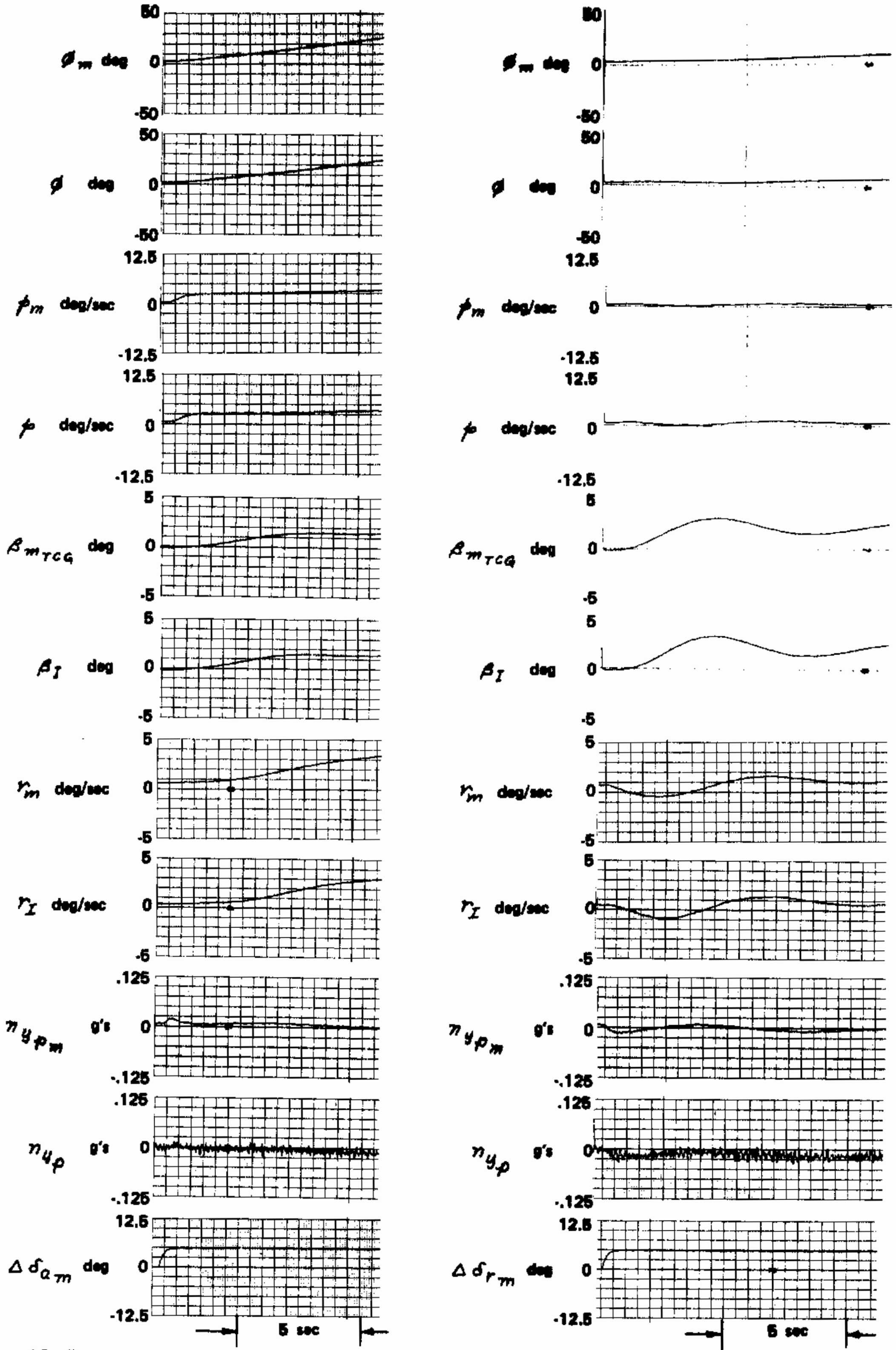


Figure V-5 Model Following Responses to Automatic Aileron and Rudder Step Inputs, Configuration P-1, Flight 96

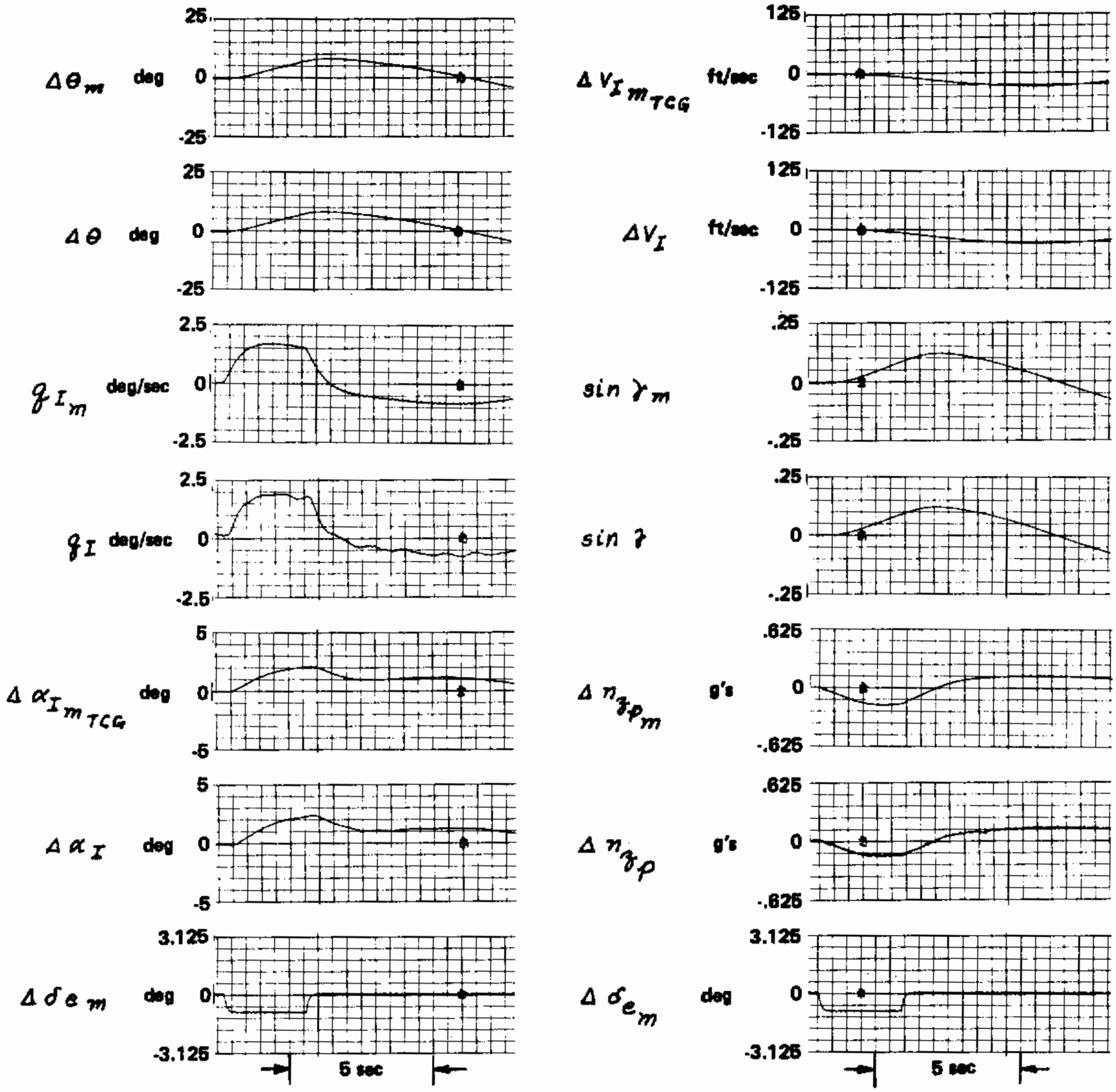


Figure V-6 Model Following Responses to an Automatic Elevator Step Input, Flight 96

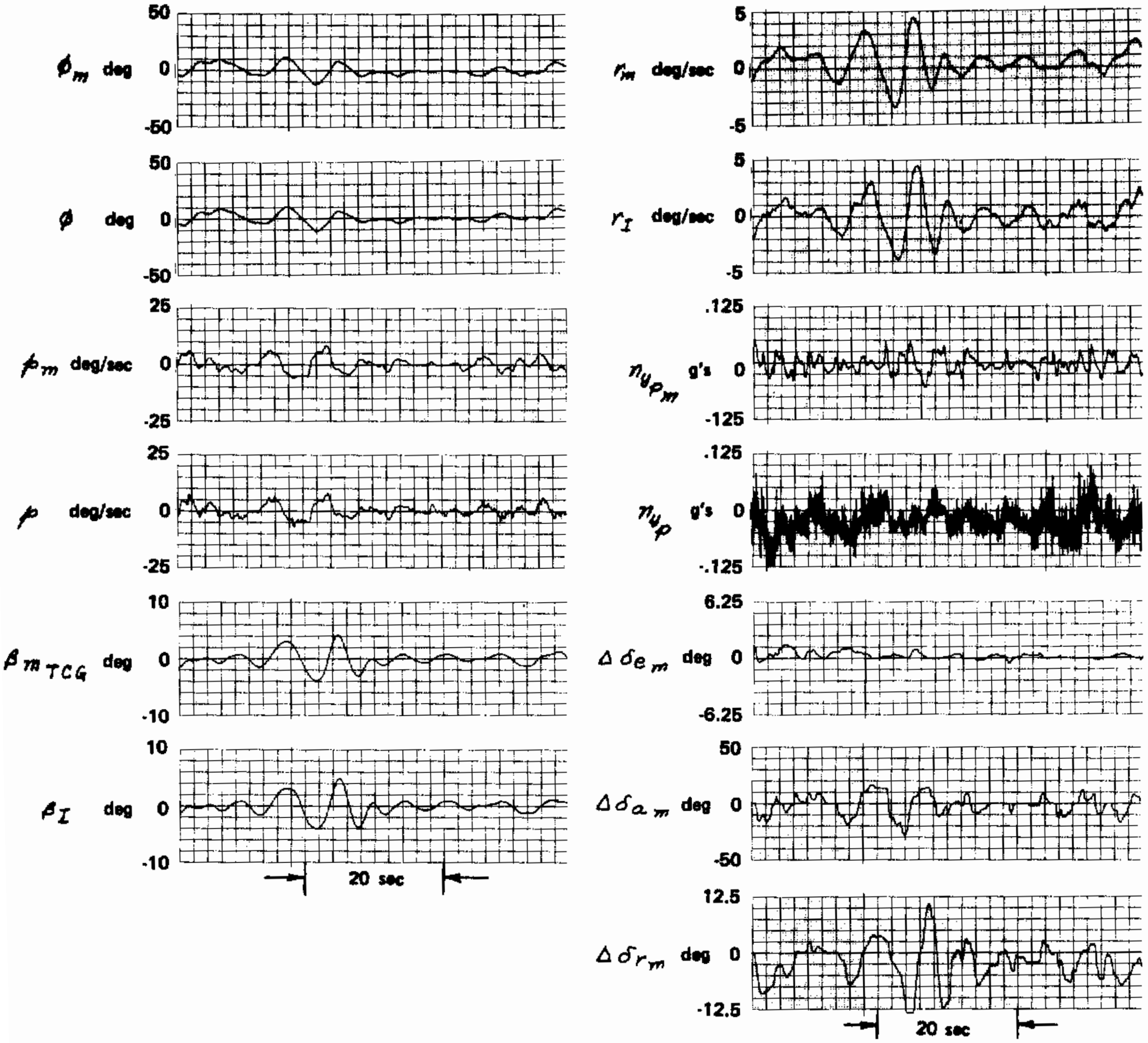


Figure V-7 Model Following During IFR Approach
Altitude ~ 1000 ft to 250 ft
Flight 89, Configuration P-8, Pilot A

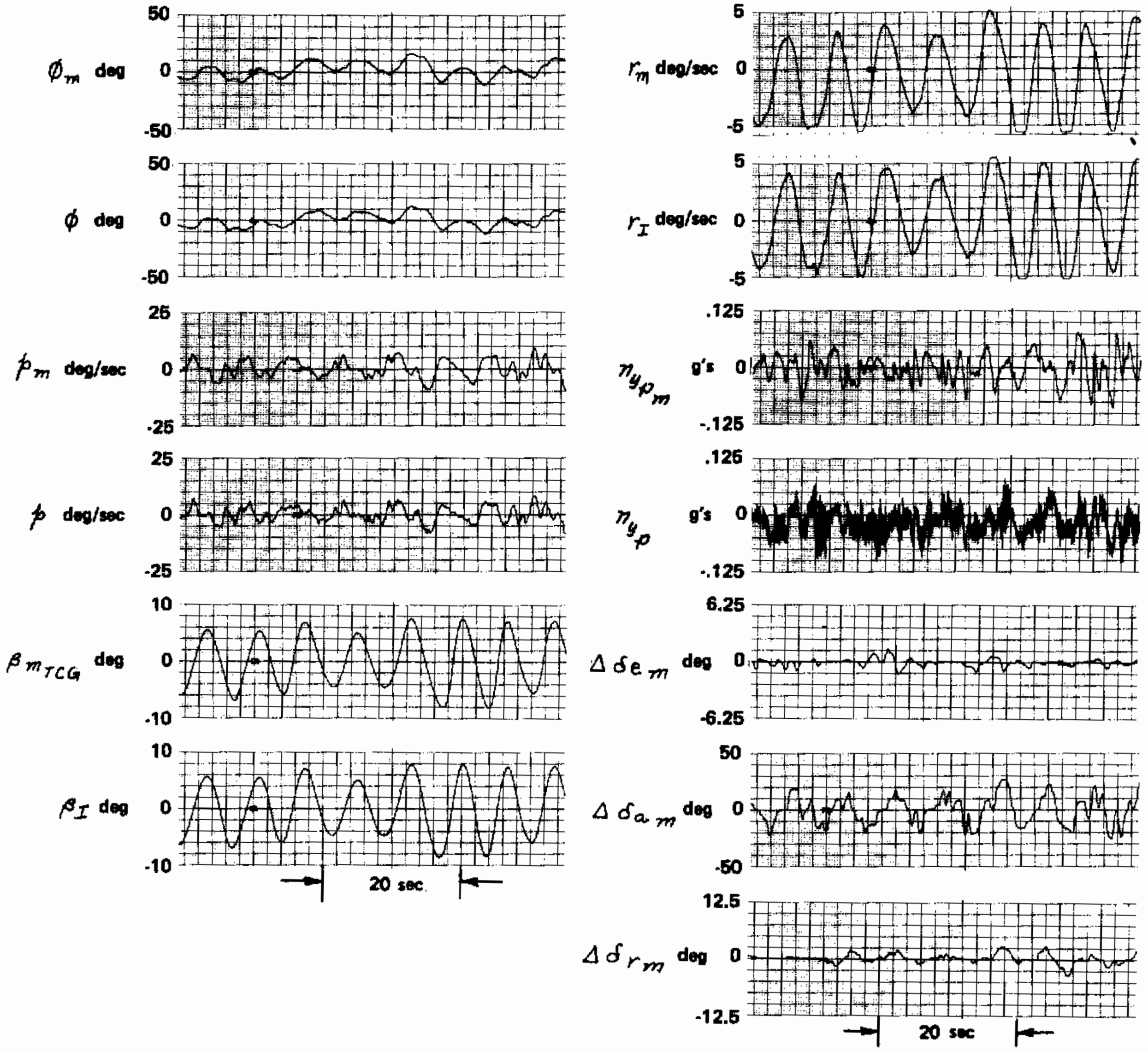


Figure V-8 Model Following During IFR Approach
Altitude ~ 1000 ft to 250 ft
Flight 93, Configuration P-8, Pilot B

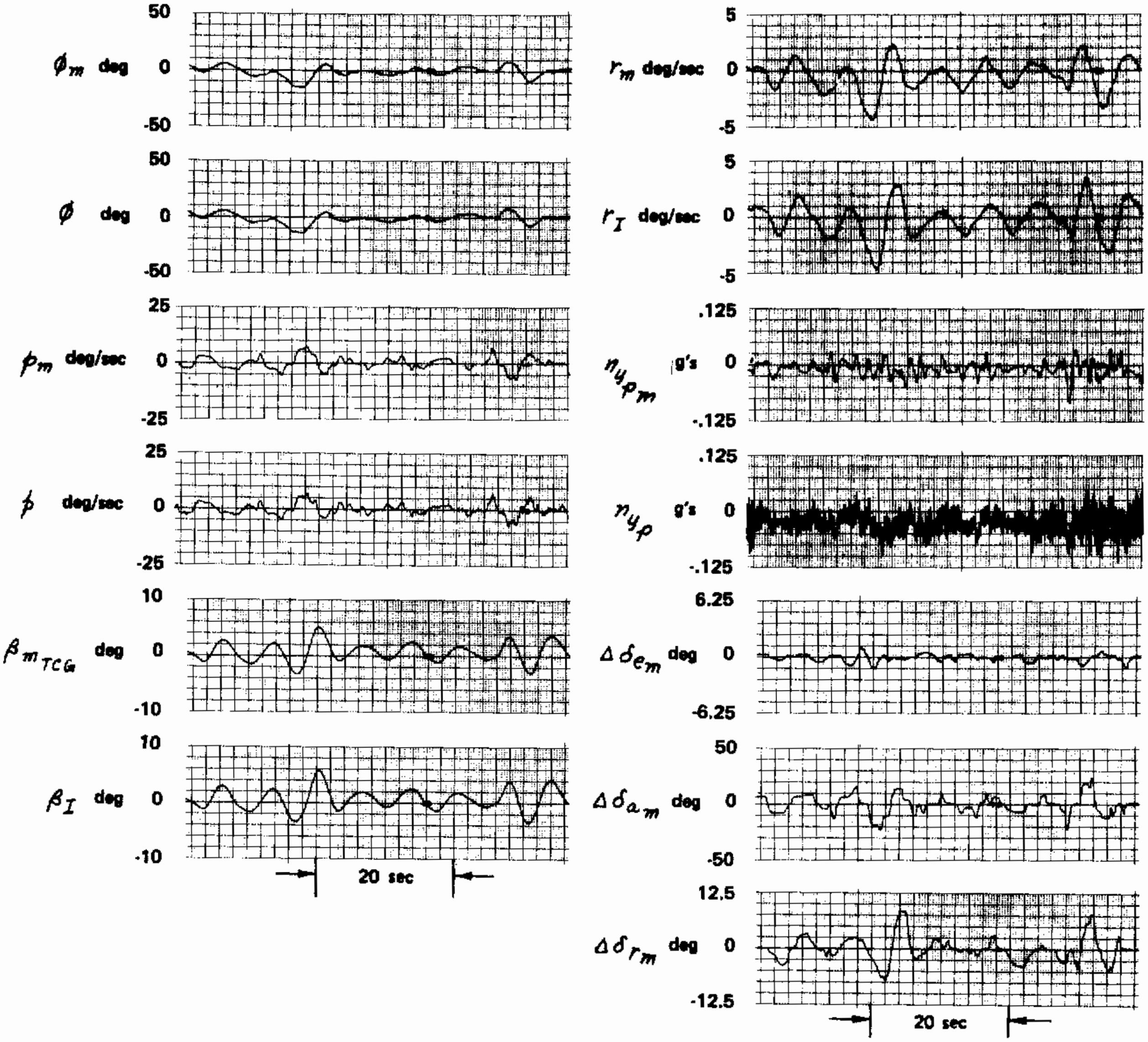


Figure V-9 Model Following During IFR Approach
Altitude ~ 1000 ft to 250 ft
Flight 101, Configuration P-8, Pilot C

APPENDIX VI

PILOT COMMENTS

This appendix contains the pilot comments transcribed from tape recording made in flight. The comments have been edited for clarification. Instructions to the evaluation pilots, comment cards, etc., are discussed in Section III.

Pilot A

Configuration P-1
Baseline

Flight No. 86

Coordination in Turns

Initial rudder was moderate to large with the turn. Secondary rudder, in the steady state, you use some rudder to help start the turn. The direction of rudder is with the turn. Once the turn is established, you gradually ease off rudder and you end up with zero rudder. You have to use that rudder every time you use aileron. Ease in accomplishing turns is between easy and moderately difficult. To make a good turn, it would be moderately difficult. A slightly sloppy entry is pretty easy. You are able to roll the airplane and stop it fairly directly. The time constant was a bit long but it did not seem long enough to hamper ability in fixing bank angle. I did not get Dutch roll excited.

Initial Response to Aileron-Only Input

The airplane yaws the wrong way with aileron-only input by a significant amount and this produces a significant lateral acceleration which is not nice and this is a disadvantage.

Ease of Achieving Desired Bank Angle

It's fairly easy to achieve a desired bank angle. The yawing acceleration and difficulties in starting a turn slow you from getting to the desired bank angle. I had no great difficulty in getting bank angle desired - it did not oscillate or overshoot. The time required to get airplane started in making these bank angle corrections is a little bit long but acceptable. I did not see any overshoot tendency in banking.

Oscillatory Characteristics (Lateral-Directional)

The lateral-directional oscillatory characteristics seem small in roll and small in yaw and the damping is quite heavy. I don't really see a residual oscillation. It is not a problem. The spiral mode did not seem to be a problem. I didn't have to control oscillations. If there is any oscillation, I used primarily aileron and somewhat rudder.

Control Feel

Force level -- on aileron is heavy but not too heavy; the elevator is heavy but not too heavy. If I were to lighten only one of them, I would lighten the elevator. I'd like to see more deflection for the same high force level. This is a gradient of δ_a/F_a. The gradient and rudder seem good. I'd like to see a little more $\Delta\delta_e$ per F_e in the elevator. Breakout forces seem good in aileron, good in rudder, good in elevator. They seemed unimportant, pretty nice. I would like a little more plain old friction in the aileron to make it stay put if it's a little out of trim.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

It's possible while playing with aileron to get elevator moving and to get longitudinal motion then you tend to oscillate a bit in pitch. The worst thing in the airplane is the longitudinal control.

ILS Beam Capture

ILS beam capture was easy. The glide slope was moderately difficult because of difficulty in controlling the airspeed and the longitudinal motion all at the same time. Rolling out on desired heading following flight director was pretty easy, VFR.

Ease of Rolling Out on Desired Heading

VFR in the landing was okay although I would like to be able to stop the turn more promptly. It's okay but not perfect.

ILS Beam Tracking

Tracking the localizer was easy, glide slope moderately difficult. Airspeed control is somewhere between moderately difficult and very difficult to keep the airspeed bang on. It was easy to roll up to the bank angle and stop it without an overshoot. It was a little slow getting started but it was still acceptable. It's difficult to change the pitch angle exactly without producing a pitch oscillation even though we have purposely cut down the elevator sensitivity to avoid this. It's quite a difficult problem to really keep the airspeed constant with the throttle which has tremendous friction and with the difficulty in pitch angle control.

Ability to Make Small Bank Angle Corrections

Ability to make small roll corrections is quite good but not ideal. It's a little slow to get the motion started then you have to do something positive to stop it. These techniques can be used and you do not overshoot but it still is not an easy airplane to roll right up to a small bank angle correction and stop right there.

Ability to Pick Up a Wing

I could pick up a wing satisfactorily. It was not easy, you had to work hard, but it was adequate.

Roll Authority

The roll authority was really more than adequate.

Trim Changes

Trim changes with power but it's small. No other trim changes. It's moderately difficult to compensate for the trim change due to power or due to a gust because of the tendency to oscillate a bit in pitch as you try to move the nose to a new pitch angle.

Would Fatigue be a Significant Factor?

Fatigue would be a problem because of the high forces but considering the decreased precision required for a long cruising flight, it wouldn't be too bad. Flying it as tight as on an ILS all the way for several hours, I think that fatigue would be a problem.

Workload

I consider the workload to be moderate. It's not small. The problem of picking the airplane up and making it move in roll requires some thought. The problems of airspeed control and pitch angle control are not small so there is a moderate workload but it's not excessive.

Most Objectionable Features

The most objectionable feature is clearly the longitudinal motion, this tendency to overshoot the pitch angle. The other objectionable feature is the slowness in rolling out and stopping on a heading and the high rudder forces required to make that happen nicely without a large lateral acceleration and without exciting the Dutch roll.

Turbulence Level on the Approach

Turbulence level was moderate; a choppy day.

Performance of Various Segments of the Mission

I performed the localizer task quite well, could return to the runway from an offset quite well. The VFR approach was satisfactory - I had the runway assured, could land it down the middle of the runway. Maneuvering the airplane around was satisfactory for the offset. I also could get it to the runway with good assurance but I was not as successful in maneuvering the airplane around from the left side of the runway to the right side of the runway and stopping right on the runway edge. I tended to move too far and I'd be outside the runway in each case. The airspeed control I consider only tolerable. Flight path control following the flight director is fairly good. Flight path control following the altitude hold on the flight director is not very good.

Configuration Rating

There is no doubt it is controllable. I think adequate performance is attainable with a tolerable pilot workload. If we were talking about a situation where all the augmenters were off, if they could get it this good, I'd say it's great. If you say this is the base airplane, this is the way it'll fly all the time, it isn't really very good, in which case I would call it a 5. There are moderate objections and it requires considerable pilot compensation, but you can attain adequate performance and I think I could keep right on obtaining adequate performance so I will rate it a 5. It's a pretty good airplane. It requires quite a lot of workload.

Pilot A	Configuration P-1 Baseline	Flight No. 90

General Comments

This configuration was a good one. I could fly it nicely, make it do what I wanted. My only complaint would be the heavy forces and the relatively long time to get a wing started to go but it was a pretty good configuration.

Coordination in Turns

The initial rudder used is a small amount with the turn or none at all. Secondary rudder used is none. Steady state was none. Ease in accomplishing turns, easy. The airplane did not slosh around very much. It was quite easy for me to make the airplane do what I wanted. I could make it stop on headings. The Dutch roll was visible and annoying in making it stop on headings but with a little effort you could make it do that. The good lateral-directional control gave me more time to play with the longitudinal control and my longitudinal performance was clearly better.

Initial Response to Aileron-Only Input

Initial motion -- it's pretty good and the lateral acceleration was negligible.

Ease of Achieving Desired Bank Angle

Achieving a desired bank angle was easy. It would have been easier if I had had less time to pick it up and get it started. Not much tendency to overshoot in roll, might have been slight but hardly any.

Oscillatory Characteristics (Lateral-Directional)

Oscillatory characteristics -- open loop - small roll, moderate yaw, heavy damping, long period, which then showed itself up when trying to fly the airplane on holding the heading. Closed loop -- no problem with roll or yaw. You could see the yaw oscillation. You didn't see any roll oscillation. I thought it was a pretty good airplane. Damping seemed sufficient. I would like to have more damping in the closed loop so I didn't oscillate around the heading that I end up with. It really is the open-loop Dutch roll damping that's affecting me there but when I am just looking at it open loop, it seems pretty good. But I do notice when I turn to a heading, it oscillates about the heading and it requires care. I have to add some rudder to make the airplane stop on the heading. The oscillation was moderately easy to control with the rudder. That's the oscillation in heading. The oscillation was excited by turbulence, by the rudder and the aileron. Moderately easy to excite with the aileron. Of course you could excite it easily with the rudder. Spiral did not seem to be a problem at all. I never noticed it.

Control Feel

Control feel -- the forces are heavy but they're that way on purpose. The rudder seemed good, a little on the heavy side, but I think that's the way I'd want the rudder. The elevator was good, it's heavy, but it's that way on purpose. I didn't really mind it. The gradient seemed reasonable for the aileron, rudder, and elevator. The maximum travel seemed reasonable for all three. Breakout forces were good on the aileron, good on the elevator, good on the rudder.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

I did not see too much cross talk because the aileron problem was easier and didn't require such big inputs. Furthermore, the lateral-directional was easy enough to do so it didn't distract me much from the pitch motion.

ILS Beam Capture

Localizer capture was easy. Glide slope was relatively easy because I could pay more attention to it. The thing that hurts the glide slope is this imprecise pitch control and the poor airspeed control.

Ease of Rolling Out on Desired Heading

Easy to roll out on a given bank angle. Easy to roll out on a heading VFR. Takes some doing, takes some rudder to coordinate the turn but still it's easy to do. Easy to roll to a heading IFR. Again it takes some rudder but you can do it. I think I did a fairly good job.

ILS Beam Tracking

Tracking the localizer was easy. Tracking the glide slope was pretty easy. It wasn't as easy as the localizer because of the difficulty of holding the airspeed and that kept it from being just plain easy, but it's a pretty good airplane.

Ability to Make Small Bank Angle Corrections

Ability to make small bank angle corrections was easy. The lack of residual oscillatory motion for small bank angle corrections was good. You did not get a lot of lateral acceleration which made you do something with the control to stop that and therefore interfere with your ability to control the bank angle so I consider the bank angle corrections easy and good.

Ability to Pick Up a Wing

Ability to pick up a wing is good. When you put in the aileron to pick up the wing, it does not do very bad things to the rest of the airplane. You do have to use some rudder but it's rudder that you can figure out how to apply.

Roll Authority

Adequate.

Trim Changes

Trim change is small with power, but no other significant trim changes. It was easy to compensate for it but still you had to do something. If you didn't, the pitch angle would go off as you changed the power in attempting to control the altitude.

Would Fatigue be a Significant Factor?

No.

Workload

The workload was moderate.

Most Objectionable Features

One is the Dutch roll period which is long and so it's hard to stop on the heading and stop right on the heading. Perhaps heavier damping would help it; perhaps a lot shorter period would help it but when turning to a heading, there is a lack of precision in stopping right on the heading. The other objectionable feature is the time required to get the wing going to make it roll and, of course, the relatively sloshy pitch control which requires some care. You will get the airplane bouncing in pitch and I don't like that, and the airspeed control is hard.

Turbulence Level on the Approach

Turbulence level was light, occasionally moderate and the rating would be "C".

Performance of Various Segments of the Mission

I felt that really all of the parts of the mission were performed quite well. I was fairly well satisfied with them. The ILS capture was precise and prompt. I overshot a little but had no difficulty in getting back on. The localizer tracking was pretty good. The altitude tracking during altitude hold at the same time maintaining airspeed was good enough. Flying down the glide path was good enough. I would like to have seen more accurate glide path control but it's hard to do with this airplane with this poor pitch control but basically it's real good ILS. I was able to perform the offset maneuver lined back up with the runway in pretty good shape with good assurance as to what I was going to do.

Configuration Rating

The rating, it's satisfactory without improving. The deficiencies are mildly unpleasant and you do require some pilot compensation so that brings it to a 3 and the compensation factors required are keeping the heading right with the rudder to damp out this Dutch roll. The slight amount of anticipation required to start and stop a turn because of the long roll and the high forces requires some effort which I wish I didn't have to do and the pitch control is not great either but still it comes out to be a 3.

Pilot B

Configuration P-1
Baseline

Flight No. 96

General Comments

None.

Coordination in Turns

Again the turns were initiated with aileron only to see what the response of the airplane would be and we had adverse yaw so that in initiating the turns, zero rudder was used. Secondary rudder was required against the turn in small to moderate amounts depending on the rate of turn. Actually the turn could be made without rudder, but on fast rate turns, for example, on the runway at low altitude, trying to track centerline or the boundary of the runway, rapid heading changes required extensive use of rudder to coordinate the turn, to keep the airplane headed straight. For steady state turns, the rudder was discoordinated both with and against the turn in moderate amounts. The turns could be accomplished. Slow rate turns were easy, whereas rapid rate turns required more concentration to keep the airplane going straight so it would be moderately difficult to difficult for a fast rate turn.

Initial Response to Aileron-Only Input

Initial response due to aileron only input was that the nose went the wrong way first and I didn't time the time required for the nose to come back in the direction of the turn. However, the sideslip induced for a 30° bank turn was about 5°. No large lateral accelerations were noted.

Ease of Achieving Desired Bank Angle

Bank angle achievement was moderately easy looking at the 10, 20 and 30° bank angles. You could roll out--near to the bank angle desired each time. There was slight overshoot tendency.

Oscillatory Characteristics (Lateral-Directional)

Lateral-directional oscillatory characteristics, open loop, rudder kicks, of course, excited the aircraft fairly well so that we went out to a 5° sideslip, steady state, then released it. The period looked like about 9 to 10 seconds and damping was positive I didn't count the number of cycles to damp. Longitudinally, this configuration has positive stability and damped out from sharp and slow elevator inputs to disturb the aircraft on the longitudinal axis. Closed loop, the largest excitement to the oscillatory characteristice was with lateral inputs. Longitudinal inputs didn't disturb the airplane very much. In fact, the longitudinal period seemed to be generally slow. Damping laterally is not enough. Longitudinally is fair. For an unaugmented airplane, the longitudinal damping might be near satisfactory and directional damping would not be satisfactory. Oscillations were controlled primarily with rudder inputs and depending on the sharpness of the turn and the tracking task attempted, it was moderately easy to difficult to control the oscillations. Oscillations were easy to excite with aileron. Turbulence I think had a minimum effect in this case. There was occasional light turbulence during the ILS approaches. Overall, all the controls were used. Some attempt was made to fly a portion of the ILS glide slope using ailerons only. Spiral influence is not noted. However, in looking at the airplane open loop, it looked like the spiral stability was near neutral and there was a low dihedral effect.

Control Feel

The control forces, gradients, travel, breakout forces, etc. have not been changed for the whole series of models looked at, they all remain in the too heavy area. The controls appear to have very little slop in them.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control inputs didn't disturb the airplane lateral-directional.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral-directional control inputs had very little effect on the longitudinal motions.

ILS Beam Capture

ILS beam capture was easy to moderately difficult for both the localizer and the glide slope. There was not a great degree of difficulty in following the flight director with this model aircraft.

Ease of Rolling Out on Desired Heading

Looking out the window at section lines, it was easy to roll out VFR on general cardinal headings, IFR moderately difficult using the heading command marker on the HSI and bank angle control was easy.

ILS Beam Tracking

Localizer tracking was between easy and moderately difficult. Glide slope the same, airspeed control the same. An excessive workload was not required here for maintaining pretty good centerline on localizer and glide slope.

Ability to Make Small Bank Angle Corrections

Bank angle corrections were moderately easy to make with this model.

Ability to Pick Up a Wing

Flying the ILS instrument approaches, the ability to pick up a wing was adequate.

Roll Authority

The roll authority, maximum roll rate could not be determined because the system would drop out. It appears though that before the system dropped out, the roll rate would be inadequate.

Trim Changes

Trim changes were not abnormal with airspeed and power changes and compensation was easy to moderately difficult.

Would Fatigue be a Significant Factor?

At the end of a long mission with an instrument approach in minimum weather conditions, high fatigue with this model would be a moderately difficult maneuver.

Workload

I would consider the workload overall on this to be in the moderate range.

Most Objectionable Features

Most objectionable feature of this particular model of course is the adverse yaw due to roll.

Turbulence Level on the Approach

Turbulence level for this flight would be, perhaps, in the "B" rating.

Performance of Various Segments of the Mission

Task performance for this model could be considered about average and maybe to an average minus.

Configuration Rating

Let's call the overall configuration rating, 5 to 5.5.

Pilot C

Configuration P-1
Baseline

Flight No. 98

General Comments

None.

Coordination in Turns

Initial rudder used is with the turn and it is a moderate amount. Secondary rudder is perhaps with the turn and in small amounts and to maintain a turn I find that I'm not really using any rudder so that it goes to zero as we are steady state in the turn. Accomplishing turns I would say that it would be easy to moderately difficult. The factors that contributed were that there was some adverse yaw present and for making turns close to the ground I found I wanted to use quite a bit of rudder as I started into the turn.

Initial Response to Aileron-Only Input

Initial response to aileron only input is that the nose hangs up and it stays there on the order of a second, a second and a half, (it's only an approximate number). A little bit objectionably long. I didn't really feel the lateral acceleration, I just felt the adverse yaw, the hangup of the nose position as I started into the turn. So I will have to say that the degree of lateral acceleration experienced was slight to negligible.

Ease of Achieving Desired Bank Angle

Achieving desired bank angle was moderately easy. The adverse yaw wasn't a nuisance in that respect. The factor contributing was just the hunting that the nose did a little bit as you were making bank angle changes. Overshoot tendency was none to slight.

Oscillatory Characteristics (Lateral-Directional)

Oscillatory characteristic (lateral-directional) was slight, small in the open-loop yaw mode and closed loop they were okay. It was not a difficult thing to damp so I will put nil. So damping I think was low and positive but it's not quite enough in yaw. I think I would like a little better damping in yaw. The oscillation was controlled by conventional use of the controls and it was fairly easy to control. Oscillations were excited with a rudder input and it was sort of difficult to excite. The control not used was the aileron for exciting this mode. I did use the aileron but it didn't excite the mode so I don't think we have a lateral oscillation, just a directional one. As far as spiral mode is concerned, again, I think it was sufficiently close to zero or neutral spiral so that it wasn't a factor. It was very nice.

Control Feel

It was good for the aileron and maybe good to slightly heavy for the rudder. The elevator was good. Gradient, the travel associated with these forces was okay in all cases, it was reasonable. I didn't get a chance to look at maximum travel, the system wasn't adequate for that. Breakout forces were light to good. I say they were nonexistent and I like that real fine.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control cross coupling to the lateral-directional modes was not a problem and not present.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

No lateral inputs to the longitudinal mode were noted.

ILS Beam Capture

The ILS beam capture and the glide slope capture I say were easy on the glide slope and moderately difficult to easy on the localizer. I don't think that the adverse yaw that I have been talking about is a significant factor in capturing or tracking the beam.

Ease of Rolling Out on Desired Heading

Rolling out on a desired heading was okay, in IFR and moderately difficult in VFR close to the ground. Rolling out on a desired bank angle was easy enough. The factor that contributed to my choice of moderately difficulty close to the ground was a requirement for quite a bit of rudder to compensate for the adverse yaw.

ILS Beam Tracking

ILS beam tracking ability was easy on the localizer and the glide slope and the airspeed I think was okay too. Now it is getting a little easier.

Ability to Make Small Bank Angle Corrections

The ability to make small bank angle corrections was moderately easy. I can't really say that I felt the adverse yaw was a significant contributing factor to that.

Ability to Pick Up a Wing

Ability to pick up a wing was okay. I say adequate to more than adequate.

Roll Authority

Roll authority was adequate or more.

Trim Changes

There were no significant trim changes with power, speed, or attitude. Ability to compensate with respect to those is not applicable.

Would Fatigue be a Significant Factor?

For cruising flight I think that this adverse yaw is an insignificant factor. I think that it would probably be a good airplane in the cruise mode. The adverse characteristics are only significant when you are VFR close to the ground.

Workload

The workload was small, and moderate close to the ground, for heading control.

Most Objectionable Features

The most objectionable features of the configuration just completed is this requirement for significant amount of rudder as you roll into turns close to the ground. I didn't notice anything particularly outstandingly good. All the other characteristics were just fine.

Turbulence Level on the Approach

The turbulence level on the approach for the first time was significant I think. More effort was required so I am going to give it a rating of B but I don't think there was a significant deterioration in performance. Just a little bit of turbulence effect. On this airplane it didn't hurt.

Performance of Various Segments of the Mission

The performance on the various segments I think was good, on a fair, good, excellent basis.

Configuration Rating

The configuration rating all together I am going to give it about 3. It's fair, some mildly unpleasant deficiencies, a minimal compensation by the pilot in the form of requirement for rudder during turns close to the ground.

Pilot A Configuration P-2 Flight No. 88

$C_{n_{\delta_a}} = 3(BL) = -.0345/rad$

General Comments

You get a small but objectionable amount of lateral acceleration in the cockpit when you initiate a turn. This apparently comes not with aileron but with the roll rate because there is a pronounced delay in picking up the lateral acceleration. This small amount of lateral acceleration makes it harder to line up with the runway. It feels as though it's sloshing out across the side of the runway and then it also interferes with your ability to control the bank angle well. You put in some aileron, things start going, and then you get this acceleration that influences you to do something different with the aileron and you end up getting a small amplitude oscillation going. So you feel as though you are working all the way down and the behavior of the airplane confirms that the airplane is rolling slightly and is yawing slightly all the way down the approach.

Coordination in Turns

I used a little rudder with the turn VFR but for ordinary IFR use I used either no rudder or very little rudder. Secondary rudder, none. Steady rudder, none. It was moderately difficult to stop it on the turn that you wanted. The lateral acceleration influences the pilot's ability to stop the turn when he wanted it to.

Initial Response to Aileron-Only Input

The yawing motion is not too bad. The nose hangs up a little. It didn't seem badly coordinated at first and then you get this lateral acceleration so that the airplane slides out. I did not see very much in the way of sideslip but I could feel the lateral acceleration. The nose hangs up for a short time. The lateral acceleration is noticeable and objectionable.

Ease of Achieving Desired Bank Angle

It's moderately easy to roll to the right bank angle in a gross sense; settling down exactly where you want is moderately difficult. Gross overshoot is negligible. For the small corrections though, you do tend to overshoot in the bank angle and so you are continually rocking the airplane through a small amplitude and this disturbs the yaw motion and is not a good situation.

Oscillatory Characteristics (Lateral-Directional)

Open loop, - it looked like the same old Dutch roll we've been seeing with a small roll, moderate yaw, well damped, pretty good looking Dutch roll but low frequency and this does influence your ability to make the airplane stop on a given heading. Closed loop - the roll is a small roll oscillation. The damping is small. The pilot tends to keep it right on going. Yaw is probably disturbed by this but I didn't notice it as explicitly. It's hard to settle down on a heading. The damping is not enough for this closed-loop situation. The oscillation was controlled in the aileron but it was difficult to ever stop the oscillation from small amplitudes. For large amplitudes it was pretty easy. The rudder was used to attempt to damp the Dutch roll motion, stop the heading. So it was difficult to control for small errors and easy to control for large errors. Oscillation was excited by the aileron and probably would have been excited by the rudder but this was not a problem and the turbulence excites it. Spiral did not seem to be a problem to me.

Control Feel

The forces are heavy but good. The rudder is good. The elevator is heavy but good. I'm not distressed by the forces. The gradient for the aileron seemed reasonable, for the rudder seemed reasonable, for the elevator seemed reasonable. Maximum travel--okay for all of them. The aileron breakout seemed okay, the rudder okay, the elevator okay.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Yes. They seemed to, but not excessively.

ILS Beam Capture

ILS beam capture was between easy and moderately difficult. It wasn't easy. It wasn't difficult either. The glide slope was moderately difficult because of the pitch characteristics of the airplane. It's not too terrible.

Ease of Rolling Out on Desired Heading

To stop on a given bank angle for small corrections is moderately difficult. To get close to the right bank angle is pretty easy. It's easy for large errors and moderately difficult for small errors. The heading IFR is not easy to stop on a given heading. To stop on a heading VFR is also not easy.

ILS Beam Tracking

Localizer tracking was moderately difficult because of this continual rolling all the way. Glide slope was moderately difficult because of the pitch characteristics, this indefiniteness in pitch. Airspeed was moderately difficult-this airplane is not easy to fly in airspeed.

Ability to Make Small Bank Angle Corrections

To make small bank angle corrections accurately is moderately difficult. For approximate corrections, then they're easy.

Ability to Pick Up a Wing

Ability to pick up a wing is adequate.

Roll Authority

Adequate.

Trim Changes

Trim change with power. I didn't see much trim change with anything else. You can compensate without much difficulty.

Would Fatigue be a Significant Factor?

I don't think you would be fatigued by it unless you had to fly with good accuracy all the time. Then it would be bad. But for ordinary flying for long periods, I would not consider this to be particularly terrible.

Workload

The workload is moderate.

Most Objectionable Features

The most objectionable feature is this lateral acceleration which induces the pilot to produce some inadvertent roll so you tend to roll about and this interferes with your ability to line the airplane up with the flight path. You roll out on the heading and it looks as though it translates sideways a little bit. All in all, it's not a terrible airplane but it's a poor airplane.

Turbulence Level on the Approach

Turbulence level--I would call it light like a "D".

Performance of Various Segments of the Mission

The capture is moderate. The localizer capture is moderate. Glide path capture moderate. The localizer capture was not as good as before. Flying down the localizer, the performance was fairly good except you're rolling all the time so that the confidence in the performance is not as good and this distracts you from performing the pitch part of the task. The glide path and the airspeed control were the same as before, fair but not great. The airspeed control on this run naturally was better than on some of the others. Lining up with the runway was possible but not easy. It was hampered by this lateral acceleration and the difficulty in making the heading right where you wanted it and the difficulty in putting the flight path right where you wanted it; even when you had the right heading it didn't seem to be where you wanted it. It had moved sideways.

Configuration Rating

The configuration rating--the task performance was adequate but it required considerable compensation and I would call it a 5 but we still could do the task that we wanted and it wasn't too terrible. The thing that made it this way was the lateral acceleration which, although not very large, was still sufficient to begin to bugger up the ease of flying the airplane.

Pilot B — Configuration P-2 — Flight No. 96

$C_{n_{\delta_a}} = 3(\text{BL}) = -.0345/\text{rad}$

General Comments

None.

Coordination in Turns

Initial rudder used was zero; secondary rudder used was with the turn and it was moderate to a large amount; steady state turn required rudder with the turn and it was moderate to a large amount; steady state turn required rudder with the turn moderate to a large amount. Coordinated turns would be moderately difficult because of the rudder required to hold in the direction of the turn to keep zero sideslip.

Initial Response to Aileron-Only Input

Initial response to aileron input only was a yawing motion at the start of the turn where the nose went opposite the direction of the turn. Well, actually, the nose tended to stay straight momentarily and then it would go opposite the direction of the turn so we had adverse yaw and then the nose would hang out in adverse yaw to about 3° indicated sideslip and would go to 5 initially when initiating a 30° bank turn and it would come from 5 maybe back to 0 sideslip and then go back out to 2 or 3° and hang away from the turn with 2 or 3° sideslips so that rudder at the end of the turn had to be used to coordinate the turn. The nose would continue to hang out in adverse yaw continuously through the turn. A little lateral acceleration was noted.

Ease of Achieving Desired Bank Angle

Bank angle achievement was moderately easy to moderately difficult. It seemed, in shooting for 10, 20 or 30° bank angles, there was a tendency to overshoot the turn just slightly.

Oscillatory Characteristics (Lateral-Directional)

Looking at the aircraft open-loop rudder kicks, it looked like about a 7 second period with positive damping and it appeared to damp to zero in a short time although I didn't count the oscillations so that the magnitudes in roll and yaw would be considered small. Had positive longitudinal stability, again short period. Closed-loop oscillations were small in both roll and yaw. Both longitudinal and directional damping are fair but not quite enough. Oscillations had to be controlled with rudder and it was moderately easy. To make a coordinated turn you had to use rudder, but just in looking at oscillation control, oscillation control itself was easy to control with both aileron and rudder. Oscillation was excited with aileron and was easy to excite with aileron. During some of the maneuvers, aileron only was used without the use of rudder in tracking task and both VFR and IFR were relatively easy. Spiral seemed to influence the task performance somewhat. However, in looking at the spiral stability, I couldn't really see that the aircraft had convergent spiral stability. It appeared to be neutral to slightly divergent. However, this could have been due to some of the turbulence encountered. It seemed that in performing the ILS task, the aircraft tended to want to roll out and it was an effort to continually put in bank angle. However, in trying to look at this open loop, it didn't bear this out.

Control Feel

Same comments as for previous flights since the system was not changed at all for any of the configurations (too heavy, too large).

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control inputs didn't cause excessive or undesirable lateral-directional motions.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral-directional control inputs didn't cause excessive or undesirable longitudinal aircraft motions.

ILS Beam Capture

ILS beam capture on the localizer was easy to moderately difficult and glide slope was the same. The slight adverse yaw due to roll and then the tendency for the nose to hang out to about 2 or 3° sideslip opposite the direction of the turn I think influences rollout on desired heading.

Ease of Rolling Out on Desired Heading

VFR was easy, IFR was moderately difficult and bank angle control was moderately difficult.

ILS Beam Tracking

ILS beam tracking ability was easy to moderately difficult in both localizer and glide slope and airspeed control.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections were moderately easy to control.

Ability to Pick Up a Wing

The ability to pick up a wing during the task performing ILS was adequate.

Roll Authority

Looking at roll authority and maximum roll rate, this could not be determined because the system dropped out each time a maximum roll rate was attempted.

Trim Changes

Trim changes negligible other than that expected for speed and power control or power changes.

Would Fatigue be a Significant Factor?

I don't feel that fatigue would be a great factor with this particular model under instrument conditions. I think it certainly would influence the exactness of the approach but it shouldn't be dangerous due to fatigue with this model.

Workload

I would consider the workload small to moderate.

Most Objectionable Features

No comment.

Turbulence Level on the Approach

Turbulence level would still be about a "B" rating.

Performance of Various Segments of the Mission

Had average performance to average minus with this configuration. One other comment on tracking task both VFR and IFR, it could be done just about as accurately with aileron only as well as using rudder and aileron even with the aircraft sideslip characteristics as noted.

Configuration Rating

Configuration rating on this one, I'd give it about 5 to 5.5.

Pilot C Configuration P-2 Flight No. 98

$C_{n_{\delta_a}}$ = 3(BL) = -.0345/rad

General Comments

None.

Coordination in Turns

Coordination in turns involved initially zero rudder and secondary zero rudder. Steady state rudder used was zero although this resulted in a slight amount of sideslip. It was not objectionable, it was very slight. The ease in accomplishing turns I'd say was quite easy. The factors contributing to the choice for this was good harmonization. For practical purposes it had zero adverse yaw. There was some long term steady state adverse yaw but it was small and it was not apparent during initial turn entries or bank angle changes even when close to the ground.

Initial Response to Aileron-Only Input

Initial response to aileron only input was that it turned just about right, it was well coordinated initially. The nose did not hang up. There was a little bit of lateral acceleration experienced which tends to make you reduce the initial aileron input slightly, whether it was $C_{n_{\delta_a}}$ or C_{n_p} I'm not sure, but it was noticeable.

Ease of Achieving Desired Bank Angle

Achieving a desired bank angle was easy. I would say that the factors contributing to that choice were that it had good roll damping, light control sensitivity, and essentially zero spiral. The spiral upon long study looks to be slightly divergent but so slightly that for all practical purposes it's a neutral spiral mode. Overshoot tendency of bank angle in roll mode was essentially none.

Oscillatory Characteristics (Lateral-Directional)

Oscillatory characteristics (lateral-directional) were small in roll and yaw both open loop and closed loop. There was no observable Dutch roll tendency. I'd say the damping was there, adequate or more. Spiral I think, was just about right and made the task easy. No change in technique due to spiral.

Control Feel

The control feel forces I would say on the aileron were between too light and good. They were very nice and light and I think a little heavying up would be desirable with this particular value of $C_{n_{\delta_a}}$ or C_{n_p} whichever it is. I'm getting a little bit of lateral acceleration due to initial aileron inputs. The rudder forces were just fine and the elevator forces were just fine. The gradient associated with the forces, the travel, was reasonable in all three cases. Maximum travel was not noted. I think for this task that maximum travel was unimportant. Now if we got to a gust problem we might have to re-evaluate that. Breakout forces were good to apparently nonexistent. Had much better centering I think than we had on the baseline airplane.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control inputs effect on lateral-directional I think is nil.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral-directional inputs affecting longitudinal is likewise nil.

ILS Beam Capture

ILS beam capture was easy and glide slope easy to moderately difficult. I think a little better speed stability might be desired. Had a little trouble with airspeed control and power control. It might just be a learning curve on power but it seems that I am making rather arbitrary changes to the power setting and waiting to see what they will do for me. I don't have the feeling but I know what 5% thrust is going to do for me or 1% or any other number. I don't have my thrust calibrated in other words. So that was a major factor that contributed to the choice of moderately difficult on glide slope capture.

Ease of Rolling Out on Desired Heading

Rolling out on a desired heading was easy. VFR and IFR and bank angles were easy. The factors that contributed to this were as previously noted, essentially a neutral spiral, light sensitivity and well coordinated sideslip control in the basic airplane.

ILS Beam Tracking

ILS beam tracking ability was easy, glide slope easy to moderately difficult as I mentioned, and I will check moderately difficult on airspeed. The factors are the same that I have mentioned above.

Ability to Make Small Bank Angle Corrections

Ability to make small bank angle corrections was easy to moderately easy, but I think this is as good as it is ever going to get for small bank angle controls in a big airplane because of the inertia that you have there. Again the factors that contributed to that are the same as above, the low apparent spiral and the well coordinated airplane laterally-directionally.

Ability to Pick Up a Wing

I didn't look at the ability to pick up a wing particularly but I think it would be fine based on the ease of rolling into and establishing desired bank angles.

Roll Authority

The roll authority, the roll rate and acceleration combined was adequate or more.

Trim Changes

Trim changes due to power and speed, attitudes were too small to be noticeable. The ability to compensate with respect to those was easy, to not observed.

Would Fatigue be a Significant Factor?

For cruising flight I think these control characteristics are just fine. I don't feel that fatigue would result from these handling qualities at all.

Workload

I consider the workload to be small.

Most Objectionable Features

The most objectionable feature noted was the lateral acceleration at the initial input of an aileron deflection. Feature that stood out as particularly good was the turn coordination, the harmonization between the lateral-directional modes so that there wasn't any apparent requirement for rudder rolling into or out of turn. It made a two control airplane and I think that is very good.

Turbulence Level on the Approach

The turbulence level was A.

Performance of Various Segments of the Mission

I think I performed the mission significantly better than I did yesterday.

Configuration Rating

I'm going to give a rating of 2 on this configuration. The salient features as before were the ease of making a coordinated turn and a two control airplane.

Pilot A

Configuration P-3

$C_{n_{\delta_a}} = -3(BL) = +.0345/rad$

Flight No. 90

General Comments

This is a terrible airplane. The nose sloshes all over with large heading excursions in the wrong direction, very large sideslip angles like 10 to 15° and every time you tried to fix it with the aileron it makes it worse. You have to just give up with the aileron and either try to fix it with the rudder or wait it out. Very poor. Surprisingly, not so poor IFR because you could control the bank angle quite well. All this sloshing about does almost nothing to the bank angle so to control the bank angle is only moderately difficult. However, precise heading holding task is essentially impossible and you can only slosh around about the mean heading and the VFR runway alignment task is very bad.

Coordination in Turns

Initial rudder used is small and then the secondary rudder used is very large with the turn. That means there's a little pause before the yawing starts. In the steady turn you don't use any rudder. Ease in accomplishing turns is very difficult if we could count turning to headings because of the wild sloshing about, very large sideslip angle induced by the use of the ailerons.

Initial Response to Aileron-Only Input

The yawing motion at the start of a turn turns the wrong way first, not right away after τ_R. I won't say the nose hangs up but it turns the wrong way and that lasts for a substantial period like several seconds, maybe 3. The lateral acceleration is only moderate. It's smooth but this very large sideslip angle and very large yaw, that is heading change, are very discouraging.

Ease of Achieving Desired Bank Angle

It's moderately easy to achieve a desired bank angle because this sloshing about affected that only minimally. There's a delay in acquiring the bank angle in the first place apparently due to τ_R and that's a nuisance. You tend to overshoot because of this sloshing about but it's really not too bad, slight to moderate, more than it has been in other configurations because this sloshing about does tend to influence the pilot to move the aileron and make things worse.

Oscillatory Characteristics (Lateral-Directional)

Open loop - it's the Dutch roll that we've been used to seeing, small roll, moderate yaw, heavy damping, long period. Closed loop - in roll you get a moderate oscillation driven by the pilot trying to do something with this aileron, and in yaw it's very bad. You get just tremendous yawing about and essentially not damped. The pilot tends to keep right on going so the damping is close to zero. There was no good way to control it. I used primarily the rudder to try to damp the oscillation but you actually did use the aileron inadvertently which kept it going. It's excited primarily by the aileron. Of course, the rudder excites it. Turbulence excites it but didn't seem to be too bad unless the turbulence put a wing down. In the process of picking the wing up, you got things going. The turbulence alone didn't seem to make it too bad. Spiral did not seem to be a problem. So we used both the aileron and the rudder but primarily the rudder to try to stop the oscillation.

Control Feel

Forces were good, rather heavy because we used so much of it. Rudder was good but seemed rather heavy because used so much. And the elevator seemed okay, heavy in the turns. Gradient for aileron, rudder and elevator all seemed reasonable. Maximum travel for aileron, rudder and elevator all seemed reasonable. Breakout forces for aileron, rudder and elevator all seemed reasonable.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Yes. With these large sideslip angles we do in fact get a pitch disturbance but partly that the attention required to handle this lateral-directional airplane diverts your attention from handling the longitudinal task and you don't do as good a job.

ILS Beam Capture

The localizer beam I would call moderately difficult to very difficult because the sloshing about makes it hard to come out on a heading that you want. I think I'd really call it very difficult. Glide slope also very difficult primarily because of the distraction caused by the sloshing about.

Ease of Rolling Out on Desired Heading

To roll to a bank angle is relatively easy and so this made the tracking task once established on the ILS not too difficult because you just made small bank angle corrections, let the airplane slosh about and the flight director was happy with it. The heading IFR was very difficult, essentially impossible and the heading VFR was very difficult, essentially impossible to make small corrections. Now, the runway alignment was very poor. If you had to make a correction and you had to make a turn, it was very poor, if you could get it lined up from fairly far back. This was true even with the offshoot, once you got it lined up, if you could then avoid disturbing the ailerons, just make heading corrections with the rudder, why you could make it go down the runway. So I think you could get it on the ground, but if a wing went down at that time and you tried to pick it up with the aileron, then that whole approach was effectively ruined. You had to go around again. You could not land it from that point on.

ILS Beam Tracking

Localizer - the corrections were from moderately difficult to very difficult because of this sloshing about. The glide slope was moderately difficult to very difficult because of these troubles. The airspeed was moderately difficult as usual.

Ability to Make Small Bank Angle Corrections

Moderately difficult to make small bank angle corrections. It would have been easy if it hadn't been for the sloshing about but it was not very difficult to make bank angle corrections because the sloshing about did not produce rolling moments directly. The yawing motion didn't couple with the rolling motion very much at all.

Ability to Pick Up a Wing

The roll is adequate but the yaw response produced is tremendous. It's unacceptable and very bad. If we count both the whole motion of the airplane, then I would say it's inadequate but the roll in itself was adequate.

Roll Authority

The roll authority was adequate.

Trim Changes

Small trim changes with power setting which I could handle rather easily.

Would Fatigue be a Significant Factor?

This certainly would be a fatiguing airplane to fly for long times but not an impossible airplane.

Workload

I consider the workload to be large.

Most Objectionable Features

The very large yaw excursions and sideslip excursions too, every time you tried to fix the bank angle. This was very bad.

Turbulence Level on the Approach

Turbulence level was light. It required more effort and about a moderate effort because of this terrible configuration but I didn't think turbulence was the major item that influenced me. The airplane doesn't roll very much in response to turbulence so since it doesn't roll very much, you don't need much aileron to correct the turbulence and this doesn't hurt you too much. I don't think I would have done a very much better job in still air.

Performance of Various Segments of the Mission

Nothing was really done very well. It's all pretty poor. You capture and you could track the ILS. It made the glide path following very hard because you're spending so much time doing all this stuff. You could do all these things poorly. The VFR is poor. The lining up with the runway can only be done if you can ever get the bank angle level when you're about lined up and leave the bank angle alone and leave the ailerons alone and fly it with the rudder for small alignment corrections. Otherwise, as soon as you try to bank the airplane and steer it over to another place, the sloshing about is exceedingly large and all wrong.

Configuration Rating

If we had to fly it in all kinds of weather, and gusts close to the runway which we do have, then it's clearly going to be a 10, because the wing will go down and as soon as the wing goes down you can no longer keep it straight down the runway. If we had a day like today, I think that I could just barely land the airplane on the runway by getting it lined up from way back and by allowing myself the possibility of more than one approach. I wouldn't guarantee that on any given approach I could get it in. So, the way I saw it, I'd rate it a 9 but I could be talked into a 10 very easily and it would be a 10 if you say you got to get it in on any given approach or if you say it's going to be rougher and more turbulence, more crosswinds, more gradient in the wind. (There is a more realistic gradient in the wind as we get down close to the runway), then I have little doubt that it would be a 10. And the difficulty in keeping the airplane aligned with the runway is what makes it a 10. You can herd it down ILS very poor, very terrible.

Pilot C Configuration P-3 Flight No. 98

$C_{n_{\delta_a}} = -3(\text{BL}) = +.0345/\text{rad}$

General Comments

The overriding adverse characteristics of the airplane force me to give it a rating of 9 assuming it has an ejection seat. The very poorly damped directional mode which tends to be divergent unless you stay right on it with a lot of rudder. It also has a little negative C_{l_β} which means that you can't stay off the aileron. You have to use the ailerons a little bit but an awful lot of adverse yaw also. You put in a little aileron and you have got to almost lead it with a lot of rudder. You make your turns essentially with the rudder and just a little aileron to try to nurse the bank angle around to where you want it. The result of this is that all the other more interesting questions had to go unanswered because of this lousy characteristic that it has in directional oscillations. If the pilot was flying this from the word go and was familiar with it I think he could manage it. I'm not sure he could handle it in any kind of turbulence or feel very confident of wanting to land it. If it occurred to him, as it should, that in a case of a damper failure I don't think he could adjust to it rapidly enough to be assured of saving the airplane. I expect he could if he was trained to know what to expect. I think he could under those circumstances in a large percentage of the cases but so many points in the mission profile that a failure which produced characteristics like this would simply catch you a few seconds behind time to the extent that there is a good chance that you would just lose the airplane in a directional divergence.

Pilot A — Configuration P-4 — Flight No. 112

$C_{n_{\delta_a}}$ = +6(BL) = -.069/rad

General Comments

It's not a good airplane. A lot of lateral acceleration every time you move the aileron which then induces a rolling oscilation driven by the pilot. The Dutch roll damping is quite good, but the closed loop damping is not very good. And this does interfere with your ability to fly the headings, fly the bank angles properly and then because of paying attention to it, it does interfere with your ability to fly the longitudinal, but still it's a flyable airplane.

Coordination in Turns

Use small initial rudder with turn, can't tell when I'm doing it, just put in an arbitrary small amount that seemed to me to be right. I don't know whether it helps very much. Secondary rudder, zero, steady state rudder, as far as I know is zero. In other words, I just have to ignore the ball sliding all around, I can't play with that. You cannot figure out a sequence of rudder motion which makes the turn come out good. Turns are moderately difficult to start and stop because of this oscillation in roll.

Initial Response to Aileron-Only Input

Nose turns the wrong way first. It's only for a short time. It's associated with the aileron, it's not Dutch roll frequency. So it's for the time that you put in the aileron, so it's of the order of a second. The lateral acceleration is excessive, it's more than I would like to have. I don't consider it good. It interferes with your task; it does not, however, make it unflyable.

Ease of Achieving Desired Bank Angle

Moderately difficult to acquire a given bank angle because of the oscillation in roll driven by the pilot in response to this lateral acceleration so you do overshoot in roll.

Oscillatory Characteristics (Lateral-Directional)

Open loop - very small roll, moderate yaw, we've got good damping relatively long period of the Dutch roll. Closed loop - you see quite a bit of oscillation in roll. The oscillation in roll induces an oscillation in yaw which is not good. The damping of the closed loop motion is poor. It tends to keep right on going for quite a while and the only way you can get rid of it is to allow, if the situation permits, you to ease off on the aileron and put it in very slowly, then the oscillation will go away, because the open loop Dutch roll is quite well damped. But if the oscillation requires you to pay attention to the ailerons and fly it exactly, and if there are disturbances which require aileron corrections then you oscillate with a small amplitude in roll and corresponding oscillation in yaw and giving you this unpleasant lateral acceleration for as long as it takes to accomplish the task that requires that tight control. So damping is not good, closed loop. You couldn't control it, closed loop. It was easy to excite with the aileron. I didn't excite it with the rudder so I don't know what happened. Probably could have. Turbulence excited it but not directly. Turbulence excites it by putting a wing down and requiring some aileron. So turbulence excites it indirectly. Turbulences makes or p which makes for which makes the oscillation. I really didn't use the rudder very much, but I did use it a little. Spiral did not seem to me to influence anything, as I was not conscious of doing anything special about the spiral. It didn't seem to be rolling off excessively or anything.

Control Feel

Ailerons are too light, it's too easy to disturb the airplane. The rudder is good, elevator is good. Aileron travel's too small, elevator and rudder okay. The maximum travel with the aileron is too small. You never could reach the maximum before airplane response required less . The rudder never reached maximum, elevator never reached maximum, but I assume they're okay. Breakout forces on the aileron, good. Rudder and elevator seem good.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Not particularly, I didn't notice too much cross-talk.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Some cross-talk because the process of paying attention to lateral-directional diverts attention from longitudinal. So in that sense there's cross-talk.

ILS Beam Capture

The localizer I thought was moderately easy. Glide slope - moderately difficult to settle down on the glide slope. The airplane is not a good airplane longitudinally. It has the same characteristics I've complained about before, squashy feeling, imprecise, difficult to drive to a pitch angle you want, to make it stop at the pitch angle you want. I find the flight path indicator, that is the indicator, really quite useful in assisting me to fly it longitudinally, it's not a good airplane longitudinally. Very easy to overshoot and slosh about. Not a precise feeling of what you're doing. Hard to control airspeed. Hard to control the power to make the airplane do what you want. The power that's required to make it fly level is hard to define, you never know what it's going to take and it changes from time to time. And the difficulty with the beam capture is this difficulty of making the airplane roll to a bank angle that you want and then make the heading stop there. Hard to make small heading corrections as required.

Ease of Rolling Out on Desired Heading

Hard to hit the bank angle that you want. Hard to hit the heading that you want. It's either moderately difficult or very difficult depending on how precise you're asking. You can't make them. To make generalized, reasonable headings is moderately difficult because of this oscillation in roll and this pronounced lateral acceleration and then it makes the Dutch roll go, it makes a pilot induce a PIO.

ILS Beam Tracking

Small corrections on the localizer are quite hard. Small corrections on the glide slope are quite hard. Airspeed is quite hard. It's not a good airplane. The airspeed changes, it's hard to correlate very well with what it's doing. The glide slope-had the difficulty in controlling the pitch angle; and the localizer, it's difficult because you have this lateral acceleration. So it's hard to go precisely to a bank angle, so you tend to oscillate in bank and this makes it hard to make the small corrections, you overshoot and have to wait and get the average of the overshoots.

Ability to Make Small Bank Angle Corrections

Hard to make small bank angle corrections because it overshoots. Connected with this, rather sensitive ailerons, I think the ailerons are too sensitive. You make it roll too fast and this lateral acceleration affects you.

Ability to Pick Up a Wing

You can pick up the wing too easily, too light aileron force.

Roll Authority

The roll authority is more than adequate, too much, causes overshoot.

Trim Changes

Trim change with power, small. I didn't see a trim change with respect to anything else. It was easy to compensate for.

Would Fatigue be a Significant Factor?

In rough air it would be a real nuisance because every time the airplane gets disturbed and you fix the bank angle, you get this lateral acceleration which disturbs the airplane in bank angle and you have an open loop oscillation going and that's bad news.

Workload

I consider the workload to be moderate to moderately large.

Most Objectionable Features

The most objectionable feature was the longitudinal imprecision, and for the lateral-directional was the lateral acceleration, the closed loop oscillation in bank angle and the ease of overshoot due to light aileron force. I don't think you should be able to disturb the airplane as easily as you can disturb this one. Nothing was particularly good.

Turbulence Level on the Approach

The turbulence was light. On the turbulence scale -- required more effort, somewhere between a C and a D. I'll call it a D.

Performance of Various Segments of the Mission

The IFR flying on the downwind leg was done fair but not better than fair in terms of altitude and heading, holding. The capture of the localizer, I did fairly well on it, but not too much better. Once I overshot because I was busy paying attention to something else, I didn't notice once the altitude got off because I was busy paying attention to the lateral-directional and didn't notice the localizer. So the localizer capture was fair. The localizer following -- fair, wasn't too bad. I could average it pretty well, but it wasn't easy. The glide path was fairly good, but required quite a lot of care and the air was not all that rough today and that helped. The flying down the runway, that's the worst part of this thing. If you have to make turns to stay lined up with the runway, it's very difficult because of this lateral acceleration, confuses the issue as to where the airplane is really finally going to go when you roll out. You roll out and the airplane sloshes out to a wrong heading and you can't seem to do much with it with the rudder. However, once you get it established down the runway and we had a fair crosswind, I had no difficulty in keeping it there. I think I could have landed the airplane without too much difficulty as far as staying lined up with the runway was concerned.

Configuration Rating

The rating on the configuration, controllable, yes. We could do adequate performance with a just sort of reasonably tolerable workload. It gets to require quite a lot of effort though, so that you have to pay pretty strict attention as you get down to the bottom. So I think I'll say requires pretty extensive pilot compensation. I had my hands full right as I got to the bottom of the ILS and things got tough before I broke out. So I'll call it a 6. Now if it wasn't a 6, the direction in which the rating would go would be a 5. That is it would not be a 7. The things that dictated this choice were the high lateral acceleration following any aileron correction. The lateral oscillation, the rolling oscillation induced by this. The difficulty in flying, making small heading corrections and the difficulty in flying the airplane longitudinally which is not good.

Pilot C

Configuration P-4

$C_{n_{\delta_a}}$ = +6(BL) = -.069/rad

Flight No. 99

General Comments

None.

Coordination in Turns

Initial rudder used has to be with the turn but it's hard to coordinate and it's sort of a large amount. The secondary rudder comes back down to, I'd say, moderate and steady state rudder a small amount, and the turn coordination is lousy. Accomplishing turns is what I'd call very difficult. Large excursion in lateral acceleration is the factor that contributes to this choice. I mean by that accompanying roll entry and roll recovery. Whenever I have a significant aileron deflection, it says I have a real sharp $C_{n_{\delta_a}}$.

Initial Response to Aileron-Only Input

Initial response to aileron only input is the large a_y . The nose hangs up, turns too slow or not at all initially and then after a while it starts turning. I didn't notice that it turned the wrong way first. It just seems to hang up and longer than previous configurations so I'm going to put about 2 seconds. I haven't any way of really timing it. It just seems like it's hanging up a long time. The lateral acceleration experienced -- is what I would call very objectionable but tolerable. I think I'm going to end up giving it a rating of 6 so I'll just put very objectionable here.

Ease of Achieving Desired Bank Angle

Achieving a desired bank angle is not so bad. I'd say that's moderately easy. It's not the bank angle that gives me the trouble. It's the rolling out on heading and the a_y that you get upon making bank angle changes. The overshoot tendency for bank angle in the roll mode -- I don't think it's so much of an overshoot. It'll tend to hang up more than it will to overshoot.

Oscillatory Characteristics (Lateral-Directional)

The oscillatory characteristics open loop are small, but closed loop, I tend to get into a Dutch roll yaw oscillation when the pilot's in the loop in both roll and yaw, so closed loop I'm going to put moderate roll and moderate yaw. The damping, I think, is okay if the pilot gets out of the loop but it's not enough with the pilot in the loop and it's due to-have I been saying the wrong thing, I think it's proverse yaw that I've got, $C_{n_{\delta_a}}$ is such that I should be using cross controls, not rudder with but rudder against. It's hanging up in the turns so that would indicate adverse, so I'll just have to say I'm confused on whether it's proverse or adverse right now. The oscillation is controlled by simply using a very gradual aileron deflection so you're controlling it mostly with aileron and by using small δ_a's. The oscillation is excited by introducing aileron. It's easy to excite with the use of any significant amount of δ_a . You tend after a while to try to get along without using the rudder, because the amount of rudder to use is difficult to determine. You're just about as well off to not use the rudder and just try to keep δ_a's small. Spiral mode did not influence task performance although I think it was apparently negative or divergent.

Control Feel

For this particular configuration, the aileron force gradient is a little bit on the light side. The rudder and the elevator are okay. The travel associated with these forces was reasonable. I think the gradients appeared relatively unimportant which I think is sort of the same thing as saying they're reasonable. I did not look at maximum travel. Breakout forces -- I did not see anything so I think I'd say that they are good and light on that, like no breakout force.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal interference not observed.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral-directional cross coupling into the longitudinal mode not observed.

ILS Beam Capture

ILS beam capture is moderately difficult just because of the difficulty of rolling out on a desired heading.

Ease of Rolling Out on Desired Heading

Ease of rolling out on a desired heading is very difficult both VFR and IFR. Bank angle I'll say moderately difficult instead of very difficult. And the factor here was apparent $C_{n_{\delta_a}}$ being excessive.

ILS Beam Tracking

ILS beam tracking ability didn't seem to be so bad. I'd say it was easy on the localizer to moderately difficult. The glide slope was easy enough. I didn't do a particularly good job of it but I don't think the glide slope and the airspeed were part of the problem. The factor that contributed to it was the inability to roll out on a precise heading. And I'd say I was lucky to roll out within ±5° initially and it took a lot of hunting around to get down to the steady state heading that was desired.

Ability to Make Small Bank Angle Corrections

The bank was moderately easy as compared to heading.

Ability to Pick Up a Wing

The ability to pick up a wing was adequate but it was interfered with by the $C_{n_{\delta_a}}$.

Roll Authority

Roll authority, acceleration and rate lumped together I'd say was more than adequate. For this particular configuration I would have liked to have had less capability because with light forces that I put in, I still seem to get a jerky response in a_y.

Trim Changes

With respect to trim changes they were nil. Therefore no compensation was required.

Would Fatigue be a Significant Factor?

For flying in cruising flight with control characteristics like this, I think it would be fatiguing. I think it would be a significant factor.

Workload

I'd say the workload was moderate to large and I have a feeling that it gives one the effect of flying rough air although there was a little bit of atmospheric turbulence noted before. It seems to me like it's quite a bit aggravated due to this a_y that we're getting whenever we try to make a heading correction.

Most Objectionable Features

The most objectionable feature of the configuration as has been stated many times in going through this questionnaire was a large a_y associated with aileron deflection and this masked any particularly good features that it might have had.

Turbulence Level on the Approach

The turbulence level on the approach -- about the same kind of air now so I would say that it has to be called "A" and therefore was light.

Performance of Various Segments of the Mission

I performed the various segments of the mission -- based on a fair, good, excellent rating, then I'd say poor.

Configuration Rating

The configuration rating, I think we're talking about a 6. It's okay. You could land the vehicle but it requires extensive pilot compensation. I think there might be wind conditions that you'd have to limit the airplane on if you were flying in this mode. The salient feature again is this large a_y associated with aileron deflection. (Glenn, you mentioned a while back that you were confused about whether you had proverse or adverse yaw because you were still getting the nose to tend to hang up, the heading would hang up for a while before starting to come around. What factors made you say that you might have had proverse yaw?) It seems to me that a time or two I tried cross controlling and it might have helped a little bit. (Yeah, but then you went back and said, well, that you still had to use initial rudder with and integrated rudder with and steady with --). Yeah, I'm going to go back and put a question mark there instead of the definite check mark and, as you know, I've for the first time noticed I've got a ball going one way and a needle going the other way on my sideslip indicator so I think that the cues to the pilot are a little bit confusing, so, let's see, cross control required at times. All in all, I think it was adverse. It just seems to me that probably while I was looking at the needle and the ball, I got this little mixed emotion about it and was thinking it was proverse. Well, I think maybe that I've got one kind of $C_{n_{\delta_a}}$ and another kind of C_{n_p}. This is just a guess. You know what I've got. I don't know what I've got. But it seems that while I got the large aileron deflection in, that I jolly well wanted to use the rudder with but maybe when I took -- put the aileron deflection back down, --- end of tape.

Pilot A Configuration P-6 Flight No. 87

$C_{\ell_\beta} = +5(BL) = -.086/rad$

General Comments

The airplane doesn't slosh around as much as preceding ones. This is quite noticeable so it makes it easier to fly. However, it's still not very good. You still tend to roll a little bit, oscillate a little bit in roll. You still tend to oscillate in pitch -- overshoot in pitch.

Coordination in Turns

I used no initial rudder and no secondary rudder, no final rudder except when I was making VFR corrections near the ground then would use a moderate rudder with the turn which now is quite noticeable. Ease in accomplishing the turns--it's fairly easy. It would be easier if you didn't have the Dutch roll going and you didn't have this tendency to oscillate in roll but the absence of the lateral kick is quite noticeable.

Initial Response to Aileron-Only Input

It turns about right although a little rudder is helpful so perhaps one might say the nose hangs up a little bit, like a second or so. The lateral acceleration is negligible and that's a very great improvement.

Ease of Achieving Desired Bank Angle

Ease of achieving the desired bank angle is moderately easy because you don't have that little kick in the lateral acceleration. You do have some tendency to overshoot in the bank angle using the ailerons. You tend to overshoot in roll slightly, and it's driven by the pilot.

Oscillatory Characteristics (Lateral-Directional)

The open-loop characteristics. There is a moderate, rather low roll to yaw ratio Dutch roll, moderate to longish period but not too long and the damping ratio quite heavy. Closed loop, you get a small oscillation in roll and a small oscillation in yaw but these are not so small as to be negligible and they're a nuisance. The damping of the open loop is good. The damping of the closed loop is quite light and you finally do get it damped out but it takes some time. The oscillation was controlled with aileron and it was moderately easy and the yawing oscillation was controlled with rudder primarily and it was not too easy. The oscillation was excited by aileron and by turbulence. Probably the rudder would have excited it but I never used the rudder to excite it. Spiral did not seem to be a factor.

Control Feel

The forces are too heavy in the aileron and too heavy in the elevator but they were selected that way and the reasons are still good. I would like to see more travel. The rudder seems about right. The travel is reasonable but I would like to see lighter forces. Breakout forces are okay.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No -- longitudinal motions did not seem to cause lateral inputs.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral motions, I think, caused longitudinal inputs. In the course of setting these rather high aileron forces, you tend to excite the longitudinal mode which then bounces as a slow bounce but it is an overshoot.

ILS Beam Capture

ILS beam capture -- localizer is fairly easy. Even though we did some rather difficult tasks, I could always end up with it. The glide slope is between easy and difficult. It's not easy to fly this airplane in pitch and particularly hard to fly it in airspeed. Airspeed just flips around. It'll change, oh, 15 knots in a second and a half.

Ease of Rolling Out on Desired Heading

Ease of roll -- it's fairly easy, somewhere between easy and difficult. The heading IFR is moderately difficult due to the Dutch roll and you can clearly see this when trying to make small corrections. Making heading changes VFR was quite good. Took a lot of rudder to do it but I had confidence that I could do it. I did not feel this lateral kick which was so distracting.

ILS Beam Tracking

ILS beam tracking, I would call it easy for the localizer; easy to difficult in the glide slope. Airspeed is difficult.

Ability to Make Small Bank Angle Corrections

Ability to make small bank angle corrections - moderately easy to moderately difficult.

Ability to Pick Up a Wing

Ability to pick up a wing, I would call adequate.

Roll Authority

The roll authority is more than adequate.

Trim Changes

Trim change with power noticeable but not uncontrollable. I would call it acceptable as it stands there.

Would Fatigue be a Significant Factor?

This is easy to fly for a long period and would not be as tiring as the preceding configuration because you don't have this lateral kick every time you do something which excites other modes.

Workload

Workload is moderate.

Most Objectionable Features

The most objectionable features are the slight overshoot in roll and the yawing oscillation which is just the same as it was before. The large objectionable characteristic is the longitudinal control which is not easy. Nothing stood out as particularly good.

Turbulence Level on the Approach

The turbulence level -- I would call it "D". There are times when I might have called it "E", so I'll call it "D" to "E" depending on where in the approach you were. I would call the turbulence moderate.

Performance of Various Segments fo the Mission

Task performance: the localizer capture I thought was pretty good. The ability to hold a heading when called on to hold a heading was only mildly good, was only moderate. It wasn't as good as it should be. The long period interferes with your ability to find out what the mean heading really is. The glide path control I'd consider mediocre due to the difficulties in controlling pitch and the difficulty, real difficulty in controlling airspeed.

Configuration Rating

The configuration rating -- adequate performance, I'd say yes-I'm talking about the lateral-directional primarily. There are deficiencies that warrant improvement but they're minor and so you can get desired performance with only moderate compensation. This certainly leads you to a 4 but you do have to work at it to make it right. However, the ability to line up with the runway after you break out is pretty good. If that were the only task, I'd get it up to a 3 and the thing that made it not that good was this oscillation in roll and yaw, the oscillation in yaw when you tried to maintain the heading that you wanted, small but still there, the tendency to overshoot in roll, small but still there, the relatively long time to start the roll going when you wanted a bank angle correction. All of these made the rating not as good as it would otherwise have been.

Pilot A Configuration P-7 Flight No. 113

C_{ℓ_β} = +10(BL) = -.172/rad

General Comments

It's a pretty good configuration. If you just rolled out with aileron alone, it did excite the Dutch roll. There wasn't much lateral acceleration, but you did excite the Dutch roll. However, it was pretty easy to figure what to do with rudders, easy and natural to figure out what to do with the rudder to suppress all this stuff. So it was quite easy then to fly the airplane reasonably accurate on the ILS. I was making 2° corrections successfully and basically I rather like it.

Coordination in Turns

Initial rudder used is small amount with the turn. Actually, this is a little bit misleading because going into the turn I used quite a bit, but it mainly was during the recovery. So in a steady-state turn, didn't use any, but recovery was when you really wanted to use the rudder and you used it to help recover and hold rudder as $\phi = 0$ was approached and this technique damped the Dutch roll very nicely. Just ease off slowly on the rudder, as the airplane settles down on that heading. This is not difficult to figure out and sort of easy and natural from a pilot's standpoint. I thought the turns were relatively easy in spite of this rudder being necessary.

Initial Response to Aileron-Only Input

The yawing, I guess was the wrong way, and I don't know how long. Lateral acceleration was small and easy to suppress by using the rudder the way I mentioned.

Ease of Achieving Desired Bank Angle

I thought it was easy to achieve the bank angle. Because you did not get much lateral acceleration, you didn't get much overshoot in bank angle and because it was easy to figure out what to do with the rudder to damp out the Dutch roll and all this other motion. If you didn't use the rudder, you get a significant sloshing Dutch roll following each aileron correction, but still not much of this sharp lateral acceleration. You just excited the Dutch roll. So in terms of the closed loop, I don't think I overshot the bank angle much.

Oscillatory Characteristics (Lateral-Directional)

Open loop, Dutch roll same as usual. Moderate yaw, small roll, a long period, relatively heavy damping. Closed loop - using the rudder you got hardly any oscillation. If you don't use rudder then you get Dutch roll oscillation. Damping was therefore high enough. The oscillation was controlled by using the rudder and of course the aileron, and I thought it was pretty easy to do. I didn't mind doing it, using rudder. The oscillation was excited by the aileron and to a mild extent by turbulence. I did use the rudder. Spiral was not a factor, never noticed it.

Control Feel

The aileron forces are good, rudder good, elevator good. The gradient was reasonable in each of the three. Maximum travel was reasonable but really not noticed. Breakout forces were good on all the surfaces, I like that amount. I wouldn't like less breakout on the aileron, I like having a little friction so I can put it somewhere and it will stay there.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

No. And the workload business was such that working on one did not hurt too much with the other one, did not absorb too much attention and so I did a better job on each mode than before. However, the longitudinal mode is still the difficult one. It's not an easy airplane to fly longitudinally.

ILS Beam Capture

I thought the localizer was easy. The glide slope was moderately difficult for all the usual reasons.

Ease of Rolling Out on Desired Heading

The roll to a bank angle was pretty easy. To roll to a heading IFR was moderately easy. You did have to use rudder, you did have to pay attention. And VFR, the same way. If you didn't have to use the rudders so explicity, it certainly would have been easier. If you didn't use the rudder, then you got this Dutch roll sloshing about and then it was hard to settle down on a heading. That's the open-loop Dutch roll, not the closed-loop instability.

ILS Beam Tracking

Small corrections on the localizer, I thought were pretty easy. Small corrections on the glide slope were easier than before because the lateral-directional stuff was so much easier that it allowed you to spend more time with the longitudinal task. Airspeed was moderately difficult as usual. But again the easier lateral-directional task allows me to do a better job on the airspeed.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections I thought were easy. No lateral acceleration or small. Easy to predict rudder required.

Ability to Pick Up a Wing

Ability to pick up a wing was excellent.

Roll Authority

Roll authority adequate.

Trim Changes

Small trim change with power, no other trim change that I saw. Easy to compensate.

Would Fatigue be a Significant Factor?

No, would have been easy.

Workload

The workload's moderate. Would have been better if I had not had this large rudder requirement and of course it would have been also a lot easier if I had a decent airplane longitudinally. This is pretty bad.

Most Objectionable Features

The most objectionable features are clearly longitudinal, and that's poor. All the reasons that I have said before are still the same reasons. Other than that, for lateral-directional - it's the large rudder compensation and I don't think it's bad either, nothing is particularly good.

Turbulence Level on the Approach

Turbulence was light to very light. And the rating, I would call it a C.

Performance of Various Segments of the Mission

I thought I had performed the various segments better than I have been performing and a better job than usual all the way down and I particularly noticed that I was able to stop on headings better when called to do so. I was better able to divide my attention between the longitudinal and the lateral-directional too, because neither one of them were so awfully terrible and in particular, the lateral-directional was enough better so that I could spend more time on the longitudinal and do a better job on that and still do a satisfactory job on the lateral-directional. Flying down the runway, I thought I could do a pretty good job. It did require rudder, you have to be aware of the fact that you could not straighten the airplane out with rudder alone. If the airplane wanted to turn, you have to bank in the direction that you wanted it to turn. Otherwise the airplane will not go. So basically, I thought I was able to do a pretty good job. There was no doubt in my mind I could have landed the airplane on the runway with the lateral-directional characteristics I had with good confidence in my ability to do this.

Configuration Rating

The configuration rating, it's controllable. Adequate performance is available with a tolerable workload. I'd say it's satisfactory without improvement and I would call it a 3. There are some fairly mild unpleasant deficiencies, but you can compensate with what I call minimum effort. Somebody might say it was more than that so I'll call it a 3. If you want to know what rating it would be if it weren't a 3, it would be a 4. And the reason is this rather large rudder required. I don't mind doing it but I can see where some people might. Now overall, with the poor longitudinal characteristics, I would call it a 5. The good lateral-directional characteristics allow more time for longitudinal so could do a better job and that's why it's not a 6.

Pilot B Configuration P-7 Flight No. 95

C_{l_β} = +10(BL) = -.172/rad

General Comments

It seems like we have a pretty good model. Directional and longitudinal damping is pretty good. Positive stability.

Coordination in Turns

Initiating the turns with aileron only induces adverse yaw. Rudder then can be used actually to coordinate the turn and it requires small rudder inputs both with and against to damp out the yaw oscillations, and actually that would be a secondary rudder used since primary is zero. Steady state turns require rudder coordination also, small inputs. Turns are easy to accomplish.

Initial Response to Aileron-Only Input

Initial response to aileron inputs is adverse yaw. The nose goes to the left first about 3° when initiating a right turn so we have the nose going the wrong way, but it didn't seem like an excessively long time before the nose started back in the proper direction. No lateral acceleration.

Ease of Achieving Desired Bank Angle

Desired bank angle is easy to achieve. Target bank angles could be hit within 1°. No or very slight overshoot or undershoot tendencies in achieving bank angle.

Oscillatory Characteristics (Lateral-Directional)

Looking at the open loop characteristics, there is a little roll due to sideslip inputs. Rudder releases, gives us about a 7 second period and I didn't see how many cycles it took to damp but more than 5 apparently. Longitudinally, the period seems to be very slow, didn't time it. It had positive stability. Oscillatory characteristics, closed loop were noted, in lateral-directional. Damping is pretty good. I wouldn't say that it's quite enough damping. Oscillations could be controlled with the rudder and pretty easy to control. Oscillations were excited primarily with aileron inputs and it was easy to excite with aileron. All turns were initiated with aileron only and then rudder was used to coordinate the turn if it appeared to help any. On this model it seems that trying to use the rudders to damp out oscillations on instruments didn't excite the oscillations any more. Spiral stability wasn't really noted and checking the aircraft for spiral stability open loop, it appeared to be about neutral.

Control Feel

They're heavy on the forces, the gradient is too large, maximum travel is too large, and the breakout forces are too heavy. There appears to be very little slop in the control system.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control inputs do not cause excessive or undesirable lateral-directional motions.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral-directional inputs did not apparently cause excessive or undesirable longitudinal motions.

ILS Beam Capture

ILS beam capture on both the localizer and glide slope was easy. The factor that contributes to that choice of course is the ease of flying the ILS and keeping the pitch and bank steering bars centered.

Ease of Rolling Out on Desired Heading

It was easy to roll out on headings both VFR and IFR and bank angle control was easy also.

ILS Beam Tracking

It is easy to track the localizer and glide slope. Airspeed control was easy also.

Ability to Make Small Bank Angle Corrections

Bank angle corrections were easy.

Ability to Pick Up a Wing

Looking at the ILS approach only, the ability to pick up a wing is adequate.

Roll Authority

I couldn't determine the actual maximum roll rate authority.

Trim Changes

Trim changes are nothing abnormal. I think the trim changes with change in airspeed and power would be considered small to moderate and normal.

Would Fatigue be a Significant Factor?

At the end of the long mission for a number of hours, an instrument approach for this model would be fairly easy under a condition of rather high fatigue.

Workload

I considered the workload here to be small to moderate.

Most Objectionable Features

The most predominant objectionable feature to this configuration is the adverse yaw due to roll but with an airplane unaugmented, actually it was pretty good.

Turbulence Level on the Approach

The turbulence level would be "A".

Performance of Various Segments of the Mission

I think the ability to perform the task for this model would be an average plus.

Configuration Rating

The configuration rating would be 3.5.

Pilot A

Configuration P-8

C_{n_p} = +3(BL) = -.315/rad

Flight No. 89

General Comments

It's a poor configuration where the nose sloshes out sideways when you turn. This is apparently associated with roll rate rather than aileron input, comes in later than the aileron input. This makes it difficult to coordinate with the rudder. I tried and you can help it quite a bit by coordinating with the rudder but it takes tremendous amounts of rudder and you don't do a very good job anyway so this is a poor configuration. However, the lateral acceleration in itself is not really too awfully high. It's this large yaw angle, large heading angle that causes the difficulty.

Coordination in Turns

You use the rudder with the turn. It takes large amounts to make anything happen. The secondary rudder, you put in moderate to start with and large a little bit later and apparently zero in steady state but it doesn't work well even when you try it. I would say it is very difficult to accomplish precision turns; moderately difficult with less precision. The factor is this large sloshing about of the nose which makes it both difficult to predict where it's going to stop and interferes with your putting in the control motion to stop the turn because this lateral motion leads you to think that something different is going to happen.

Initial Response to Aileron-Only Input

Yawing motion turns much too much the wrong way and it does not turn just with aileron. It apparently turns some with aileron and more with roll rate and then when you take the aileron out, you don't know what to do with the rudder, so it's very difficult to coordinate. The lateral acceleration was present and annoying but not particularly high.

Ease of Achieving Desired Bank Angle

Moderately difficult to achieve a desired bank angle and stop at it, because of the factors I just mentioned. You overshoot in roll but not very much. It's only slight. The main thing is that while this is going on, the airplane is sloshing around so the heading is changing. The flight path isn't really changing as much as you'd like it to. However, there is not much interaction between all that sideslip and all that yawing and the roll of the airplane does not respond in roll to that large sideslip.

Oscillatory Characteristics (Lateral-Directional)

Open loop, it's the same as we've seen before, small roll, moderate yaw, good damping, long period. The long period is a disadvantage. It shows up later in the closed-loop heading holding problem. Closed loop, it oscillates in yaw as you try to fix the roll by a lot and then as you try to fix the roll, to readjust the roll, then it oscillates back the other way and it's quite poor. The damping of that closed loop is not good enough. The oscillation was controlled. It was difficult to control. You used rudder and some aileron. Aileron made it worse but rudder was hard to figure out so nothing really worked. The oscillation was excited primarily by the aileron and you could excite it by the rudder but that isn't what you did. Turbulence excited it but not too much. The spiral did not seem to be a problem. It didn't show up as a spiral. I did nothing special to stop it.

Control Feel

Aileron forces seemed reasonable. I'm no longer complaining that they were too heavy. Rudder seemed good or too heavy because now I'm using such quantities of rudder. Elevator seems good and on the heavy side. The aileron gradient seemed reasonable, as did rudder, and elevator. The maximum travel seemed reasonable in all respects. I never did hit the stops on the rudder even with these large values. I wouldn't have wanted much more travel. The breakout force in the elevator was good, the aileron is good, rudder is also okay.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Yes, because you're working so hard with the lateral-directional, you tend to upset the airplane in both rudder and aileron. I think that using all that rudder upsets the airplane in pitch. The cross-talk is bothersome, that is, the difficulties with the lateral-directional certainly did contribute to poor pitch performance. My altitude control, airspeed control, glide path control, were not as good as usual.

ILS Beam Capture

The localizer was between easy and difficult and you had to rack it around but you could make the bank angle come out to what you wanted and then sooner or later the heading angle would go to what you wanted. Glide slope was moderately difficult because apparently you disturbed it with this aileron input or lateral-directional inputs of some kind and besides, you had less time to pay attention to the airspeed, the pitch angle and the glide path. It was a problem.

Ease of Rolling Out on Desired Heading

The roll to the desired bank angle is between easy and moderately difficult, not too bad to roll to the bank angle. To roll to the heading IFR was really quite difficult for a precise heading. You essentially just about couldn't do it. To roll to somewhere in the ball park of the heading was still not easy. It was moderately difficult. VFR to change the heading, it was not good because it was hard to predict where the heading was going to finally end up when you rolled out because of this large yaw motion that got started. So it was not a good airplane in any way to get to the heading.

ILS Beam Tracking

Localizer was between easy and difficult because you were distracted by this stuff and the glide slope was quite difficult and the airspeed the same way because of being distracted by this terrible lateral-directional motion and also the possibility of cross talk between the rudder motion and the pitching motion.

Ability to Make Small Bank Angle Corrections

Moderately easy to make small bank angle corrections. This large sloshing motion didn't really affect that very much.

Ability to Pick Up a Wing

Ability to pick up a wing is adequate but poor behavior, lots of yaw, but wing did come up.

Roll Authority

The roll authority was adequate.

Trim Changes

Trim change with power, a small trim change as before, again relatively easy to compensate but getting more difficult because of the general difficulty with the longitudinal motion caused by the lousy lateral-directional motion.

Would Fatigue be a Significant Factor?

If I only had to fly the airplane loosely and rough air was not bothering me, I do not think this would be more than an aggravating airplane. If you had to fly it very closely, the fatigue would be a significant factor.

Workload

Workload is moderate to large, trying to compensate for this miserable lateral-directional stuff.

Most Objectionable Features

The most objectionable feature is clearly the way the nose sloshes out sideways as you call for a roll correction coupled with the difficulty in predicting exactly what rudder you should put in to help it. Rudder with aileron won't do. Rudder with roll rate is hard to puzzle out what to do and especially when you're recovering from the turn, then rudder with roll rate becomes difficult to predict and so this is clearly the most objectionable feature. The low frequency Dutch roll which then makes the airplane slosh around the desired heading and the amplitude selected by this rapidity of the correction, is really quite objectionable.

Turbulence Level on the Approach

Turbulence level was light and so I would call it about a "C".

Performance of Various Segments of the Mission

The ILS capture was actually fairly good. You could fly the bank angle, fly the flight director fairly well. The localizer holding was fairly good for the same reason. The airspeed control was poor. The flight path control was poor even though you presumably didn't change the longitudinal. The elevator forces now seemed large as I was trying to do something with it. The recovery to the center line from the offset maneuver was moderately well performed in spite of this terrible heading correction but if you then tried to make a quick correction, the heading went way off. I thought that was performed poorly.

Configuration Rating

I would say adequate performance is not obtainable with a tolerable workload. The deficiencies certainly require improvement and the controllability wasn't really in question. I could even get it over the runway when I wanted it. I don't know that it wasn't in question, but I could do it. So maybe it's an 8, maybe it's a 7. I think I'd call it an 8. The thing that contributes to that rating is that it's too hard to make it fly down the runway. If I had to change this rating from an 8, I would change it in the direction of a 7 because I can more or less get it to fly down the runway but I'm really working at it and I would hate to have only one shot at doing it so I think I'll call it an 8 but I could be teased into a rating of 7. The thing that makes it bad is this wild sloshing of the nose when you're trying to line the airplane up with the runway. If you do it slowly, gently, you can do it, if the circumstances require that you quickly pick up a wing, the nose will go way off and then I don't think you'd be able to do it well at all.

Pilot B | Configuration P-8 | Flight No. 93

$C_{n_p} = 3(BL) = -.315/rad$

General Comments

This is a very sloppy airplane directionally. Excessive yaw due to roll. Period directionally about 10 to 12 seconds, very slow. Longitudinally, aircraft is stable but a slow period. I didn't time the nose -- putting in a doublet nose down and then up and releasing it, the nose returns toward the trim position but very slowly.

Coordination in Turns

Initially VFR, no rudder was used in initiating the turn. However, due to the yaw which you get in initiating a turn which is about 10° of adverse yaw with an aileron input, rudder was used then to correct for this adverse yaw so that the rudder gets the turn and a large amount was required and to maintain a steady state turn using rudder and trying to coordinate it. The rudder just had to be coordinated both with and against the turn to try to maintain the relatively coordinated turn. To accomplish a coordinated turn was very difficult that was using rudder. Without rudder a coordinated turn of course would be impossible.

Initial Response to Aileron-Only Input

Initial response to aileron input, of course, was that the nose went in the opposite direction. To roll to a 30° bank the nose would give us a sideslip of about 10° adverse yaw. I didn't time how long it was before the nose would come back to the direction of the turn again but it was a relatively long time, then of course the yaw would be very large in the opposite direction as well. No lateral accelerations were noticed that were significant.

Ease of Achieving Desired Bank Angle

Bank angle achievement again was moderately easy, not too difficult to get the bank angle desired. The reason for the comment on the bank angle is that it was fairly easy to roll out on a desired bank angle without excessive undershoot or overshoot.

Oscillatory Characteristics (Lateral-Directional)

Open loop there was again a little yaw due to roll and rudder kicks as I stated already gave a period of around 10 to 12 seconds and I didn't count the oscillations until the directional inputs were fully damped out. Longitudinally, the nose was slow to return to the trim condition. Closed loop of course, there's excessive yaw due to roll and again moderate roll due to induced sideslip. Damping, of course, directionally is pretty good but the excursions are excessive within the closed loop. Damping is not considered enough, though, directionally. Longitudinally, it would be fair. I had to control the oscillation with rudder visually; it was reasonably-moderately easy to difficult to damp the airplane out directionally using the rudder. However, on instruments, it was easy to couple with the yaw and actually make the aircraft diverge in yaw, trying to damp it out with the rudders, so flying instruments it was better to stay off the rudders. Directional oscillations were easily started with aileron inputs and of course it was very easy to excite the aircraft directionally by trying to use any rudder. Turbulence of course would have an effect here also. It would make the aircraft more difficult to control. However, the turbulence factor was fairly negligent in this case. Spiral stability was not difficult to control.

Control Feel

There was no change in the control feel for this configuration, so the comment will be the same as for the first configuration.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control inputs didn't set up any lateral-directional motions.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral-directional motions, of course, disturbed the airplane on all axes.

ILS Beam Capture

ILS beam capture was difficult because of the excessive yaw due to roll and because of excessive Dutch roll oscillations that were set up, it made the glide slope difficult also.

Ease of Rolling Out on Desired Heading

Rolling out on desired heading was difficult because of the yaw due to roll, and this was more difficult for IFR than for VFR.

ILS Beam Tracking

The localizer and glide slope were both difficult because of the Dutch roll oscillations set up.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections were difficult again for the same reason, adverse yaw due to roll.

Ability to Pick Up a Wing

Could pick up a wing fairly well.

Roll Authority

Roll authority again in the barely adequate category.

Trim Changes

Trim changes were not significant other than what was expected with airspeed and power changes.

Would Fatigue be a Significant Factor?

Landing would be hazardous under normal conditions but under fatigue conditions it would probably be near impossible.

Workload

The workload was large.

Most Objectionable Features

The objectionable features of the configuration were excessive yaw due to roll. No particularly good features noted.

Turbulence Level on the Approach

The turbulence level would be "A" to "B".

Performance of Various Segments of the Mission

The performance of the task would be below average for the mission.

Configuration Rating

The rating for this configuration would be 9 to 10.

Pilot C | Configuration P-8 | Flight No. 101

$C_{n_p} = 3(BL) = -.315/rad$

General Comments

None.

Coordination in Turns

You have to use the rudder with the turn. You have to use a fairly large amount of it and you don't have to use much aileron. Secondary, you get into an oscillation and so you have to just use the rudder against and with and you just have to keep working the damn rudder all the time because it has this long wallowing directional oscillation. In steady state you've got to use it with and against and even using it you can't really control β. Accomplishing turns is very difficult. The factor that contributes to this is that poorly damped, long lateral oscillation.

Initial Response to Aileron-Only Input

Initial response to an aileron-only input is that the nose turns the wrong way first and then comes sweeping through and you have to watch your sideslip indicator. I think that for an airplane like this, the sideslip indicator to find out what the c.g. is doing, is a very essential element. We got up to sideslip excursions of ±10° or more on most of these turn entries. The lateral acceleration isn't so bad. It's just the smooth adverse yaw and the long undamped directional oscillation that results from trying to use the ailerons.

Ease of Achieving Desired Bank Angle

Achieving desired bank angle is very difficult because of the ϕ/V_e characteristics of the airplane. You start a bank and then the C_{n_p} causes the directional oscillation to commence and this in effect produces a C_{l_β} which tends to stop your bank so you get a sort of a lunge and a stop and a surge and a stop in bank angle as you try to get over towards a desired bank angle. The overshoot tendency is there. It's just as likely to be an undershoot. I'm going to say overshoot tendency and undershoot tendency because it's just oscillatory. And I'll put large down here.

Oscillatory Characteristics (Lateral-Directional)

The oscillatory characteristics in the lateral-directional mode are--in yaw, they are large both open loop and closed loop. In roll, I guess you'd say they're small and it's not so much a roll oscillation as it is a hesitation in roll. You don't have any C_{l_β}. I think I said earlier that the C_{l_β} is probably stopping the rolling motion. I don't know what's really stopping the rolling motion but if you just put in pure rudder, you don't get any roll with the direction of the rudder application. In fact, I think, if anything you get an apparent negative dihedral effect. It's slight, wallowy and smooth but you can pick a wing up with rudder. Back to the oscillatory characteristics, there's very little damping. Id say it probably takes many cycles to half amplitude and it's definitely not enough. The oscillation is controlled by rather large and smooth rudder inputs and even then the control is fairly ineffective. You have to be in phase with the sideslip and you have to keep continuously changing your rudder input. I'd say the period is something on the order of 10 seconds for the directional oscillation. It may not be that long but it seems like it's that long and it's extremely difficult to control. It has to be done with rudder. And then you just keep using the aileron to try to get what little roll rate you want to oscillate around a desired bank angle. The oscillation is excited by either aileron or rudder and it's too easy to excite. I am sure it would also be excited by turbulence but it was not observed. I'm not sure what the turbulence factor was. I didn't detect any high frequency turbulence and I was all over the sky when I was under the hood with that thing so I don't really know what the turbulence was. If one of the controls is not used to damp it, it would be δ_a because the rudder is the primary control for that directional oscillation as it turns out. The apparent spiral is still close to zero. I would tend to think it's slightly divergent but I'm hesitant to make that judgment. It's mostly just oscillatory and it has an apparent convergence when you're trying to roll into a bank angle because of the effect of the directional oscillation on roll rate. It just stops it and then starts it up again. I think if you let it, it would probably end up being fairly neutral but at times it seems convergent and at other times it seems divergent. I think it's because of that big wallowing Dutch roll.

Control Feel

I'd say for these derivatives that we've probably got pretty good force gradients on aileron, rudder and elevator. It seemed like I was using quite a bit of rudder force to offset that directional oscillation so it might be that we would be in favor of lightening up the rudder force gradient so I'll say that it's good to too heavy. The gradient, the travel associated with these forces is probably reasonable. The limitations of the VSS system are such that it's fairly easy to kick the system out with aileron inputs but you're not getting a whole lot of aileron effectiveness there so I think that if the system could hack larger control deflections that we would have a reasonable gradient. The maximum travel was not observed. No breakout forces were perceived. I think they were good as far as the way they felt is concerned.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

I noticed that while I was in the lateral oscillations trying to control bank angle that I had difficulty with nose attitude control and so I think for the first time in this series of flights, we've seen a case where the lateral-directional input caused excessive or undesirable longitudinal airplane motions.

ILS Beam Capture

ILS beam capture was difficult. Glide slope capture was moderately difficult because you're so busy with that lateral-directional that you don't have a lot of time to pay attention to pitch mode.

Ease of Rolling Out on Desired Heading

Rolling out on a desired heading is very difficult. VFR, I would just say it's moderately difficult to very difficult. IFR, it's very difficult and bank angle control is very difficult. That's because of the directional oscillation which is so poorly damped and has such a long wallowing period.

ILS Beam Tracking

ILS beam tracking on the localizer was moderate to very difficult. Glide slope was moderately difficult. Airspeed was moderately difficult.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections were very difficult because you simply couldn't stabilize. You always oscillate in bank angle and in heading around 5° in each direction. You just simply couldn't hold either one steady.

Ability to Pick Up a Wing

The ability to pick up a wing was inadequate not because of the control power but because of the directional oscillation excited by any aileron movement.

Roll Authority

Roll authority was, I'd say, just barely adequate.

Trim Changes

Regarding the trim changes with respect to power, speed and attitude, I think it's probably the trim changes due to being in such large sideslip and those were large for the first time. Ability to compensate for them was very difficult.

Would Fatigue be a Significant Factor?

If you'd been flying in cruising flight, I think you'd get awfully damned tired of this thing before long. You'd need some relief. So, I think this one would be fatiguing for any lengthy period.

Workload

The workload I believe is large.

Most Objectionable Features

To repeat the objectionable feature, it is the adverse C_{n_p} that comes in with the initiation of a bank which in turn stops the roll rate. It's not as though it's roll damping, it's as though it's dihedral effect. But the directional oscillation being undamped, it'll tend to roll you back out or if you put in some more aileron and start it up again, it'll aggravate the oscillation and it's just a very wallowing motion and masked any good features that this airplane might have.

Turbulence Level on the Approach

The turbulence level in the approach was probably "A" to "B". I think I'm unable to determine that because of the lousy characteristics of the airplane.

Performance of Various Segments of the Mission

I think I performed it poorly.

Configuration Rating

The pilot rating on this--I think it's very objectionable. The deficiencies are barely tolerated. You can land the airplane but it requires extensive pilot compensation. I'm sort of debating between a 6 and a 6.5. For the short term and emergency operation, I think I could give it a 6 and the salient features have been well covered above.

Pilot A | Configuration P-9 | Flight No. 113

$C_{n_p} = -3(BL) = +.315/rad$

General Comments

It's a bad airplane. Aileron produces a large amount of acceleration in sideslip and yawing rate and put together in a way where it's very difficult to figure out what to do with it. In fact we found that maintaining the ball in the center manually will produce a lot of sideslip and maintaining the sideslip zero manually using the rudder following the sideslip indicator will give you lots of ball motion or lateral acceleration. And there's no way you can get them both to come out right. If you blend them VFR, not using the instruments so much but just going by the general appearance and feel of the motion, lateral acceleration is sensed by the pilot making the yaw rate come out proportional to the bank angle, you can do a fairly good job. You have to use a sequence of rudder to do it and I don't like doing it, but IFR, it's almost impossible. You also get a large lateral displacement when you make a bank angle correction down close to the ground. You roll out just as you get to the right flight path and roll out to make the bank angle level right at that point and the airplane slides off sideways and that's not good.

Coordination in Turns

The initial rudder used is either zero or large against the turn, depending on your technique. The secondary rudder, I guess you use a sort of small amount against the turn or moderate amount against the turn. And then the secondary rudder is rather large against the turn and you don't use any steady state rudder, and it's difficult. You think of it as wrong rudder with aileron and then ease rudder off to suppress the Dutch roll. The turns I'd call pretty difficult due to the factors I've just been talking about, especially in the beginning of the comments, namely the large excitation of the Dutch roll, you do nothing with the rudder and the peculiar time history of the rudder required to make something happen and then the difficulty of actually carrying it out. I don't know how to keep the airplane from moving laterally across the field. I must have the wings level. Nothing I could do would keep the airplane from moving laterally across the field as I rolled out of the turn. I didn't think much of this.

Initial Response to Aileron-Only Input

Yaw goes the wrong way first, I guess. Lateral acceleration is fairly large, not as large as we have felt lateral acceleration, and smooth n_y, but phasing is hard to figure out.

Ease of Achieving Desired Bank Angle

Achieving a desired bank angle is moderately difficult because you can't figure out what to do with it and then you do tend to get an oscillation going in roll angle, closed loop, and this tends to make oscillations in yaw which are quite significant. So you do get a moderate overshoot in the bank angle.

Oscillatory Characteristics (Lateral-Directional)

Open loop - same old airplane. Small roll, moderate yaw, long period, light, rather heavy damping. Closed loop - no rudder, you get a moderate oscillation in roll and a moderate oscillation in yaw and with rudder, you get less, but never could suppress it all. Damping of the open loop is pretty good, although because you excite it so much it looks worse than it otherwise would. Closed loop, it's not great. You do tend to keep the motion going, driving this closed-loop oscillation, so the damping is not good enough. The oscillation was controlled with aileron, you have to use aileron to keep the airplane from banking and especially with the spiral that we've got. So rather difficult to control and difficult to use rudder, well, you're using them both. Oscillation was excited although it could be excited with the rudder, it was primarily excited with the aileron. Turbulence was not much of a factor at least the turbulence that we had today. It's the aileron that caused the trouble. The spiral didn't seem to affect me directly, except it meant I had to use some aileron to keep from spiralling off and using the aileron made this oscillation get worse.

Control Feel

The feel; ailerons, too light; rudders, okay; and the elevator's okay. The gradient's too small and the rudder and elevator are okay. The gradient on the aileron was too small. Maximum travel - never reached. Breakout forces seemed okay in all axes.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Only by diverting attention.

ILS Beam Capture

Localizer, beam capture is moderately difficult because of the difficulty in getting the bank angle that you wanted. Glide slope was moderately difficult because of the poor pitch characteristics of this airplane and also because you're distracted by poor lateral-directional characteristics which required quite a lot of time.

Ease of Rolling Out on Desired Heading

Bank angle is pretty difficult. Getting a heading IFR, I'd call very difficult because of the difficulty in stopping the bank angle where you want it, and get this lateral acceleration going. Also the Dutch roll makes the flight director needle go when you're in the approach mode, even though the bank angle isn't moving. This is characteristic of the flight director, it'll do this and does not help matters.

ILS Beam Tracking

Ability to make small localizer corrections was hard with this poor ability to get the bank angle you want and it's continually exciting the motion by using the aileron. Glide slope was moderately difficult and airspeed, as usual, due to the poor longitudinal characteristics of this airplane that we've talked about before.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections are pretty difficult because of this oscillation that is driven by whatever happens to make the ailerons go. Incidentally it seemed like N_{δ_a} and N_p are both in there, different amounts of them.

Ability to Pick Up a Wing

Ability to pick up a wing is poor - not lack of control, just lack of prediction of what the airplane's going to do when it does come up. In other words, you can pick the wing up, but then you excite the Dutch roll and the airplane goes sloshing way off of response and excitation of large Dutch roll while picking up wing.

Roll Authority

Roll authority is adequate.

Trim Changes

Small trim change with power, no other trim change that I saw, easy to compensate for.

Would Fatigue be a Significant Factor?

A poor airplane to fly for a long period.

Workload

Workload is large.

Most Objectionable Features

The most objectionable feature is this sloshing about, everytime you try to move the ailerons and the inability to do very much about it with the rudder. And nothing was very good.

Turbulence Level on the Approach

Turbulence level was light and I think I would call the rating about D.

Performance of Various Segments of the Mission

I thought nothing was performed very well, but not all of it was too bad. Just flying along VFR was not too bad as long as you could keep things small, keep disturbances small. And IFR, same thing was true, not bad as long as everything was small. You didn't have any task to do. Then capturing the localizer, making the turns, the headings was not easy, and not done very well because of the difficulty in stopping on a heading and the distraction of that interfering with your ability. Turning on to the localizer was difficult for the same reason, difficult to stop on the localizer, on the heading that you want and therefore difficult to stop with the heading that you wanted. When you roll out, the airplane doesn't necessarily stop turning, it does some different things and it's hard to predict what it is going to do. It may do the same thing each time, but the pilot isn't prepared for that happening. Small corrections on the localizer were not easy because of this difficulty in establishing a heading and also the ease of exciting a closed loop oscillation in roll which then would drive a substantially larger oscillation in yaw which was not conducive to good performance on the localizer. The glide path performance was compromised by the excessive attention required by the lateral-directional stuff and besides it's a poor airplane in pitch anyway. Flying down the runway, lining up with a runway, if you ever got it lined up and didn't do anything then you could get on the runway. I think I could have got it on the runway, I think I could have landed it, but it was not a good airplane. If it wasn't lined up and you tried to fix it as you made your turn, the airplane would slosh around in a rather difficult way to predict. When you come around tangent to the line you want on the runway, the airplane would then depart laterally a significant amount and this is a bad thing. So if you have to make any corrections it's not good. If you don't have to make any corrections, it's all right. So really that's a pretty poor characteristics, and I didn't like that at all. The passengers were complaining about the airplane being sick, but of course that doesn't bother the cockpit very much.

Configuration Rating

Is it controllable? yes. Is it adequate performance attainable with a tolerable workload? The answer is no, and I'm defining this in terms of the corrections on the localizer, especially when life gets tough and you have to make them quick and sharp, can't just ease around on them as you're getting close to the bottom and also I'm defining it in terms of lining up on the runway once you break out. So I think I'd say it requires pretty intense compensation. You have to do something and I'll call it a 9. I don't like it at all, it's a very poor airplane. I've already talked about what the major deficiencies were. I wish to talk a little bit more about this business about the inability to use the rudder. I spent quite a bit of time trying to learn how to use the rudder and for entering into gentle turns and for recovering from gentle turns, you use wrong rudder along with the aileron and it would work. So that if you're in a right turn and you're recovering then you use, must be bottom rudder. Anyway, you use it the wrong way and you have to not time it directly with the aileron, but as you recover from the turn, you still hold some rudder in there to keep from oscillating, you ease the rudder out at what I presume is a Dutch roll frequency, but it just seemed like slowly and smoothly and it can be done. You don't end up with a perfect job, you end up with the ball a little off and the sideslip a little off, but you end up with a fairly acceptable job. But you can't do it quickly, you forget what to do. You can't do it when you're on instruments and life gets complicated for the same reason. You forget what to do and this other technique requires careful attention and isn't practical. And then if you try to fly just the ball, the sideslip goes all over, really terrible and if you try to fly just the sideslip, the ball goes all over, really terrible. Neither technique will work. In other words a sideslip fixer or a lateral acceleration fixer in the stability augmentation system won't work with this configuration. And the pilot can't learn to do it either. You have to learn to blend them in some fashion where you weight them both and do something that seems about right. So that's really a knock against this configuration, this inability to figure out what to do with the rudder and so I didn't like it and that's why I rated it so poor.

Pilot B Configuration P-9 Flight No. 94

$C_{n_p} = -3(BL) = +.315$

General Comments

This configuration has too much proverse yaw. Flying VFR headings is relatively easy. However, using instrument headings, using HSI, you tend to get in a lateral PIO. The lateral-directional damping looks like a period of about 8 - 10 seconds and the damping is pretty good. Directional inputs are damped out in about 4 or 5 cycles. Longitudinal damping is fair to poor. The nose hung up for a doublet input in the nose up position for a good while before it started back down. However, it is positively stable.

Coordination in Turns

There was no rudder used initially backup rudder -- used rudder against the turn small to moderate amounts and steady state turn took some rudder coordination. That would be both with and against the turn moderate amounts. VFR--the turns were moderately difficult VFR, and IFR I would put it under the difficult category because you tend to get in a lateral PIO when trying to really hold a heading.

Initial Response to Aileron-Only Input

Initial response to the aileron was that the nose turns too fast. Actually you have proverse yaw and there is too much proverse yaw. Again differentiating VFR and IFR, IFR controls tend to aggravate the situation. In VFR the yawing motion is controlled easier. No particular lateral acceleration noticed in the cockpit in turns.

Ease of Achieving Desired Bank Angle

It was moderately easy to achieve bank angle. Could roll out pretty well on any bank angle desired without significant overshoot or undershoot and this was checked in rolling from 30 to 20 to 10° bank angles.

Oscillatory Characteristics (Lateral-Directional)

Open loop, directionally, the aircraft would damp in about a 10 cycle period with about 4 to 5 cycle damping required. Longitudinally, damping was poor, did have positive stability. The airplane closed loop had proverse yaw which, VFR, handling qualities and directional control were fair looking out the window. But IFR, the roll control was okay, directional control was poor. Damping is probably not good enough directionally; longitudinally okay for an unaugmented airplane. Control of the oscillations primarily using the rudder and that was typical with IFR. Oscillations were excited by aileron and it was easy to excite. Turbulence may have some effect but it's difficult to tell really what effect the turbulence had on this and I think basically all the controls were used when flying the airplane. For the IFR approaches, I primarily used aileron to initiate all the turns and would try to use some rudder if I felt like it was helpful. However it seemed to aggravate the aircraft rather than help. Couldn't really say anything significant about spiral mode.

Control Feel

I feel the aileron and rudder forces, elevator forces are too heavy. The gradient is too large and maximum travel is still a little bit too large for all of them. Breakout forces are too heavy.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control inputs didn't seem to affect lateral-directional too much, just pure longitudinal inputs didn't excite the airplane directionally.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral-directional inputs caused the aircraft to be disturbed about all axes.

ILS Beam Capture

ILS beam capture was moderately difficult to difficult for both localizer and glide slope because of the tendency to get into a lateral PIO, because of excessive proverse yaw when trying to control the headings very fine.

Ease of Rolling Out on Desired Heading

The rolling out on desired heading, tracking the needle, is moderately difficult VFR, and is difficult IFR.

ILS Beam Tracking

Tracking is difficult for both the localizer and the glide slope and I did notice a little more problem with the airspeed control on this configuration, again because of excessive proverse yaw.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections I think were only moderately difficult as compared to larger bank angle corrections. The tendency for making small corrections seemed to be less for getting into your lateral PIO.

Ability to Pick Up a Wing

Adequate performance in picking up a wing.

Roll Authority

Maximum roll rate authority I would classify just barely adequate.

Trim Changes

Trim changes were nothing other than what was expected with airspeed and power changes we're making and I was able to compensate. I'll call this moderately difficult on airspeed control.

Would Fatigue be a Significant Factor?

I think that this configuration would be a very poor one to have at the end of a long mission. I think fatigue factor certainly would make a rather hazardous instrument approach with low ceiling, poor visibility.

Workload

I would consider the workload large.

Most Objectionable Features

The most objectionable feature is the excitation of the aircraft on all axes by the excessive proverse yaw. If any feature does stand out as particularly good compared to the others, it may be that airspeed control is fairly responsive.

Turbulence Level on the Approach

Turbulence level on the approach I would rate as about a "D" and at this time maybe light to moderate.

Performance of Various Segments of the Mission

Mission performance with this configuration I think would be poor.

Configuration Rating

Configuration rating would be close to a 9 and maybe an 8 minus.

Pilot C Configuration P-9 Flight No. 99

C_{n_p} = -3(BL) = +.315/rad

General Comments

None.

Coordination in Turns

The use of rudder isn't very satisfactory with this condition. It's not as bad as the previous as far as the $C_{n_{\delta_a}}$ is concerned but it's still objectionable and rather than try to coordinate it with rudder, it looks like you're just about as well off to leave the rudders on the floor for the IFR turns. The VFR is another matter. So for an IFR turn specifically, if you just assume that you've got essentially no proverse, no adverse, you're in pretty good shape. I think I remember noticing that they were slightly proverse if you really studied it but if you looked out the window at the wrong angle, you could get the impression that it was slightly adverse because you were below the roll axis in the pilot's seat, if the point I was choosing to look at was below the roll axis, so I'll check zero rudder on all three cases. Ease in accomplishing turns I would call moderately difficult because of this small to moderate a_y.

Initial Response to Aileron-Only Input

Initial response to aileron only-input is that it starts changing heading for you right away. It doesn't hang up. The yawing motion is therefore probably just about right but you still get some a_y which is undesirable. As to the degree of this objectionable lateral acceleration, whereas before it was very objectionable, this time I think I would call it somewhere between minor and moderate. I think it probably would be on the order of 4.5 so I'll just put minor to moderate.

Ease of Achieving Desired Bank Angle

Achieving desired bank angle is moderately difficult. I seem to notice in this configuration more than the last one that the bank angle tends to wander around as you try to relax your δ_a to zero when you're approaching a desired bank angle. It's not as easy to roll out on a precise bank angle as you'd like for it to be. The overshoot tendency of bank angle is slight and likewise with undershoot.

Oscillatory Characteristics (Lateral-Directional)

Oscillatory characteristics (lateral-directional)--magnitude, I'd say small to moderate and it seems to me like that's mostly in yaw so I'll put small to moderate in yaw and small in roll. I don't recall seeing it really in rolls to speak of. Closed loop it's a little bit worse. I'd say it's moderate in roll and yaw closed loop. Pilot tends to aggravate it. I'd say it damps in about 2 cycles and I'd like to see it more. The oscillation was controlled mostly by just letting it go. You're better just to open the loop. Once you did that, it was fairly well damped. It was easy to control open loop and it's difficult to control closed loop. You could excite the oscillation with the rudder. There was no apparent C_{l_β}. Perhaps slightly negative dihedral effect but very close to zero and if you stabbed the aileron, you didn't seem to get into an oscillation. If you stab the rudder and let it go, you could get into the oscillation. If one of the controls was not used, it would have to be, in this case, δ_a . Spiral mode was insignificantly divergent.

Control Feel

Control feel I think was pretty good. The ailerons were good, the rudder was good, and the elevator was good. The travel associated with these forces was reasonable in all cases and the maximum travel was not observed. Breakout forces were good to negligible.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control inputs had no influence on lateral-directional.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral-directional inputs had no effect on longitudinal.

ILS Beam Capture

ILS beam capture was, I'd say, relatively easy. I'll check both easy and moderately difficult. It was really sort of in between those two and glide slope the same. The only factor which deteriorated my ability to capture the glide slope was this inability to roll out on a heading you'd like to roll out on. We also had some crosswind which may have been a contributing factor but I'm not sure that hurt.

Ease of Rolling Out on Desired Heading

Ease of rolling out on a desired heading was moderately difficult. The bank angle seemed to be more difficult to achieve than the last configuration. The heading was easier, but the bank angle was more difficult. And the factor that contributed to this was, I think I'd say, slightly more oscillatory directional characteristics but the reduced $C_{n_{\delta_a}}$ effect.

ILS Beam Tracking

ILS beam tracking was about the same as before, I think. Localizer was easy to moderately difficult. The glide slope was easy enough and airspeed was easy enough. Factors were the same as mentioned above.

Ability to Make Small Bank Angle Corrections

Ability to make small bank angle corrections was moderately difficult. At this point, I might mention that if we were talking about ϕ/v_e, we might find that that was a little bit worse on this configuration than the last one. This yawing oscillation which tended to carry itself on a little further was accompained by oscillatory, small and a fairly long period surges in ϕ which I think is what detracted from our ability to make these small bank angle corrections.

Ability to Pick Up a Wing

Ability to pick up a wing was okay. Had more than adequate control power. Picking it up was easy enough but stopping it when I got it there was another thing.

Roll Authority

The roll authority, the roll rate and acceleration capability I think were more than adequate, felt very nice.

Trim Changes

The trim changes were nil due to power, speed, attitude or any other factor. Ability to compensate with respect to those items was not applicable.

Would Fatigue be a Significant Factor?

For cruising flight long term, I think in smooth air you wouldn't have any problem at all. In rough air, you might find it slightly fatiguing.

Workload

The workload I think in that case was moderate.

Most Objectionable Features

It seemed like I had some $C_{n_{\delta_a}}$ and it wasn't as bad as the previous configuration, which, although it didn't affect the rolling into a turn so much, it affected rolling out of the turn on the desired heading and it also tended to make the pilot, when he was in a loop, produce simulated rough air because he tried to control it and it required a little cross controlling due to the proverse yaw. No particular features stood out as being real good.

Turbulence Level on the Approach

The turbulence level on the approach, I think I'll say "A" to "B" not really knowing because when the pilot is in the loop, he tends to create his own lateral-directional upsets but there was a considerable crosswind reported at Niagara Falls. I think they said something like 250 and I don't think I ever got the velocity of it. So, I'll check light to moderate under turbulence. And under the rating I'll put down "B" to "C" for rough air.

Performance of Various Segments of the Mission

I think I'd say fair in this case.

Configuration Rating

Configuration rating was considerably better than the last one at 4.5. And the salient features that dictated this choice of rating were the slight apparent proverse yaw and the apparent mild but still noticeable $C_{n_{\delta_a}}$.

Pilot A Configuration P-12 Flight No. 91

$C_{n_p} = +3(\mathrm{BL}) = -.315/\mathrm{rad}$

$C_{l_\beta} = +5(\mathrm{BL}) = -.086/\mathrm{rad}$

General Comments

This was not a good configuration. It sloshed sideways when you put in some aileron, changed the heading quite a bit. Hard to correct with the rudder. A difficult one to evaluate. I didn't really make enough runs to give it as much as I would like, so this is a little bit sketchy, but I think it will be all right. Most of the time it seemed not too bad and once in a while when you had to do something relatively sudden with the ailerons you found you really had a terrible airplane. It would slosh around and you couldn't fix it very well with the rudder.

Coordination in Turns

Initial rudder, if you used it al all, you used it with the turn, but it didn't work very well. If you used it at all, you used a lot so you either use a lot or zero and most of the time you use zero. Perhaps it would be better to call that the secondary rudder because you used it a little bit afterwards. It was hard to do. Steady state rudder seemed zero. Ease in accomplishing turns was moderately difficult. I didn't like this to make turns with and there was this sloshing about which then got the airplane moving and you could sense that and it was confusing to the pilot, almost nauseating, almost vertigo producing, this yawing motion with no roll and no apparent reason for it.

Initial Response to Aileron-Only Input

At the start the nose hangs up a little bit and then it turns the wrong way, a whole lot, and that's not good. It hangs up for maybe a second. The lateral acceleration is moderate and smooth, annoying, and degrades the configuration.

Ease of Achieving Desired Bank Angle

Ease in achieving desired bank angle was moderately difficult because this yaw acceleration comes in and disturbs and distracts the pilot. It's not easy to predict what it's going to do. That makes you tend to overshoot in bank, a moderate overshoot.

Oscillatory Characteristics (Lateral-Directional)

Open loop same as before. Small roll, moderate yaw, quite heavy damping, long period which shows up in the difficulty in turning to and stopping on a heading. Closed loop, you get a pronounced yawing oscillation if you use the ailerons and you get a small to moderate rolling oscillation which is hard to get rid of. It doesn't go away soon enough. This is the major trouble with the airplane. Tried to control the oscillation - with the aileron it was hard. I tried to control it with the rudder and it was hard so

I used them both, but it was hard no matter what you did. It was excited easily with the aileron. I suppose it would have been easy to excite with the rudder but we didn't do that. Turbulence excited it not too much. Spiral was no problem to me in this configuration.

Control Free

Forces seem good to heavy on the aileron, good on the rudder, and good to heavy on the elevator. The gradient was reasonable for all three. The travel was reasonable on all three. The breakout forces seemed good on all of them, heavy on the aileron and rudder but I think I put them there on purpose.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Yes. But not so much as far as I can see in the direct way. The lateral problem takes up so much time, you don't have as much time left over for the longitudinal problem so you don't do as well, so there seems to be cross talk.

ILS Beam Capture

The localizer is moderately difficult because of this difficulty in stopping a turn where you want it. Moderately difficult on the glide slope because of the interference with the lateral-directional and because of this rather spongy longitudinal control, poor airspeed control.

Ease of Rolling Out on Desired Heading

Not easy to roll out on the bank angle. It takes a long time to get started, long time to stop and then this yawing oscillation gets started, has a significant interference with your ability to stop the bank angle, partly direct coupling of the motion but not so much that as that the yawing angular acceleration and the lateral "g" make the pilot think something's going on and he tends to use the ailerons which keeps the rolling motion oscillating instead of stopping at the bank angle you want. Turning to a heading IFR is pretty difficult to make it stop where you want. The Dutch roll gets started so whenever you stop on a heading with a large sloshing effect, you overshoot with the heading and then it comes back quite slowly and it's not an easy one to stop on a heading IFR. Changing heading VFR, if you make only small corrections it's moderately difficult. For any large correction, it's very difficult and you slide sideways off the side of the runway. The only thing to do is to get it lined up and don't touch anything with the aileron then you could make it go down the runway fairly well. But anything worse than that is terrible.

ILS Beam Tracking

Beam tracking is relatively poor, relatively difficult because of this sloshing about with the lateral acceleration, the large yawing motion for every little correction you make, and that shows up in the flight director when you're down low and you've captured the ILS beam and then the heading shows up so it really complicates the heading task. Glide slope task is moderately difficult, airspeed is moderately difficult for all the reasons we've talked about before, the poor longitudinal.

Ability to Make Small Bank Angle Corrections

Moderately difficult.

Ability to Pick Up a Wing

Inadequate. Although it rolls ok excessive yaw is excited and it interferes.

Roll Authority

Adequate or more.

Trim Changes

Trim changes are small, and moderately different to compensate.

Would Fatigue be a Significant Factor?

Comment no obtained.

Workload

Large workload.

Most Objectionable Features

The most objectionable feature is clearly the yawing motion following aileron which is excessive, gives you lots of sideslip and doesn't disturb the roll directly but induces the pilot to disturb the roll. It's confusing to the pilot and it makes the heading corrections difficult, specially on the glide slope part of the ILS when the flight director looks at heading and this is clearly bad. The longitudinal motion is not good and that complicates your life.

Turbulence Level on the Approach

The turbulence level was light to moderate. It interfered more so I would call it an "F" on the rating in terms of the way it interferes with the task.

Performance of Various Segments of the Mission

Nothing was done very well. The capture was fair. The localizer flying was fair to poor because of the heading sloshing. The ability to fly down the runway was marginal. If you got everything organized so that you had it set and didn't have to disturb the ailerons, then it would fly down the runway and you can get to it fairly well. I think I could have landed it but if you had to make a correction it was poor, very poor. The airspeed control was poor. The flight path was performed moderately well but I certainly was operating under difficulties to do it.

Configuration Rating

Marginal configuration. I'll call it a 7. If it wasn't a 7, it would be a 6 -- certainly would not be an 8. It's very objectionable but I don't think they're tolerable. The difficulty is that performance is just about obtainable but I would still say 7. I think if the wind were a little stronger, and the air a little rougher and I had to pick up wings close to the runway, I would then be in real trouble. So I guess I'll call it a 7. It is this tendency to slosh when you put in some aileron which is hard to control and which makes the airplane move laterally across the runway which is bad. Now if you didn't have that, if you could get all set up and just drive straight in and not have a wing go down, then you could land it. Including longitudinal, it would also be a 7. That didn't make it that much worse but it certainly was not good.

Pilot C

Configuration P-12

C_{n_p} = +3(BL) = -.315/rad

C_{l_β} = +5(BL) = -.086/rad

Flight No. 101

General Comments

None

Coordination in Turns

Coordination in turns is lousy. Initial rudder used is zero. Secondary rudder used is a large amount with the turn. It's as though we've got some C_{n_p}, not $C_{n_{\delta_a}}$ and the steady state rudder used is with and against and it's in large amounts because you get into a poorly damped directional oscillation. Accomplishing turns is very difficult. It's not as bad as the last configuration but the general characteristics are the same so this is going to sound like a repeat of configuration P-8, but in all cases, I think the adverse characteristics are slightly less bad.

Initial Response to Aileron-Only Input

The initial response to an aileron-only input is that, first of all, your nose goes in the wrong way and then it starts to swing around with you accompanied by a large excursion in sideslip and this directional oscillation continues. You can do some good with it with moderate amounts of rudder pedal. The lateral accelerations experienced are so smooth that you don't feel them. You're more impressed by the sideslip excursions in heading and in indicated sideslip angle. I'm sure that they're there but the jerk is so small that it's difficult to say how large the lateral acceleration is.

Ease of Achieving Desired Bank Angle

Ease of achieving a desired bank angle is moderately difficult and it's due to these directional oscillations. The overshoot tendency for bank angle is oscillatory so it's not really an overshoot or an undershoot thing. You start your roll and everything's fine until the sideslip builds up and brings the roll rate down to zero and then you start to roll some more. Considerably easier than the previous configuration.

Oscillatory Characteristics (Lateral-Directional)

The open loop magnitude of the roll oscillation is small but it's moderate to large in yaw. I think we were seeing sideslip angles between 5 and 10° this time compared to the 10 or 11° on the previous configuration. Closed loop--again it's small in roll but it's moderate in yaw. You could do some good. It looks like it may damp to one half amplitude in about 3 cycles. Not nearly enough here. You are oscillating all the time. Okay, oscillation was controlled by the use of the rudder and the aileron had very little effect on it. It was difficult to control. It was excited by aileron. It didn't seem to excite very easily with rudder. We had heavy rudder forces in order to affect the sideslip angle. The rudder did not excite it. It was easy to excite with aileron, and difficult to excite with rudder and it was not observed with respect to turbulence. The spiral mode was masked by the directional oscillatory characteristics although it appeared to be slightly confusing as did the last configuration.

Control Feel

The forces, as far as the aileron is concerned, it was good. As far as the rudders were concerned, I think I'd say it was too heavy and the aileron forces were good. The gradient or travel with these forces were reasonable in all cases even with respect to the rudder. The maximum travel was not investigated as on previous configurations because of the system limitations. Breakout forces appeared to be nonexistent so I'd say good on all three modes. I think maybe here, we're starting to see a little bit of dead band so I'm going to check good to too much.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

The longitudinal did not affect the lateral-directional.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

The lateral-directional control inputs caused excursions in sideslip which, at the larger bank angles, tended to create longitudinal problems.

ILS Beam Capture

ILS beam capture was moderately difficult. Glide slope capture was easy to moderately difficult. The factors contributing to this choice were the undamped directional oscillations.

Ease of Rolling Out on Desired Heading

Rolling out on a desired heading, I'd say was moderately difficult to very difficult. And on IFR, it was very difficult. You could roll out and then you'd oscillate ±4 or 5° around the desired heading and then after a while, it would damp out and it would be okay but initially it was difficult. Likewise, achieving a desired bank angle was moderately difficult to very difficult because of these oscillatory characteristics.

ILS Beam Tracking

ILS beam tracking was moderately difficult. Glide slope tracking was easy to moderately difficult. Airspeed control was easy to moderately difficult. And again, the factor that contributed to this was this directional oscillation that caused the bank angle oscillation and the heading oscillation which tended to demand an excessive amount of attention and also rather large rudder forces.

Ability to Make Small Bank Angle Corrections

The ability to make small bank angle corrections was very difficult. You could do it ±3° or 5° of bank, ± about the same in heading and that's about all you could do regardless of how hard you tried and to do that, it distracted you from your attention to glide path, airspeed, and other problems. The factor again was this undamped directional oscillation.

Ability to Pick Up a Wing

We had more than adequate aileron power to pick up a wing but it excited the directional oscillation which made it unsatisfactory.

Roll Authority

Roll authority was, I'd say, just adequate.

Trim Changes

I think that the trim changes were small and they were due to this directional oscillation so I'll put $\Delta\beta$ down here. Ability to compensate with respect to those items was moderately difficult.

Would Fatigue be a Significant Factor?

I think this would be a very tiresome airplane to fly for any length of time.

Workload

I consider the workload again to be large.

Most Objectionable Features

The most objectionable feature was the poorly damped, fairly long period directional oscillation which was easy to excite and hard to control and this masked any outstandingly good features that the airplane might have.

Turbulence Level on the Approach

The turbulence was light to moderate turbulence so I'll put down "B" to "C" on this on the turbulence rating and check light to moderate.

Performance of Various Segments of the Mission

As far as the performance of the various segments of the mission is concerned, I think that compared to the last time, I did fair instead of quite as poor but required quite a bit of workload to do it.

Configuration Rating

The rating, I think since this one was significantly better than the last one, I'm inclined to give it just about a 5, the salient feature again being the same as our previous configuration, namely that there's a fairly large, poorly damped directional oscillation that's excited by trying to change the bank angle of the airplane. It appears to be a C_{n_p} type thing.

Pilot A

Configuration P-13
$C_{n_p} = -3(BL) = +.315/\text{rad}$
$C_{l_\beta} = +5(BL) = -.086/\text{rad}$

Flight No. 114

General Comments

You can make the airplane go pretty much where you want it to go and line it up with the runway so it's not terrible and it's not good either.

Coordination in Turns

You use a little rudder with the turn and then you use quite a bit later on with the turn, easing off to damp the Dutch roll and there's no steady-state rudder. Turns are moderately difficult because of this.

Initial Response to Aileron-Only Input

The yawing motion turns the wrong way at first and this happens quickly, then you get the slow Dutch roll overshoot. So the mix is unfortunate. It responds quickly at first, you think it ought to respond quickly later and it doesn't. It starts off turning the wrong way quickly and then you get this long slow overshoot of the Dutch roll which interferes with your ability to predict what it's going to do. If it was all fast or all slow, it would be better, I think, but still not good. The lateral acceleration is not particularly high. The airplane does slosh around, but not with this high, sudden, almost jerky lateral acceleration. So that wasn't so bad just in itself.

Ease of Achieving Desired Bank Angle

Achieving a desired bank angle was moderately difficult because you get a closed-loop overshoot in bank angle as the airplane swings around and you use the ailerons to correct for this swinging. Then the same aileron disturbs the motions still more and you get this closed-loop instability, it oscillates in yaw and feeds back through the roll, I didn't like that. So it does overshoot in bank angle when you're trying to fly it, this is closed loop.

Oscillatory Characteristics (Lateral-Directional)

The open-loop Dutch roll, same as before. Small roll, mdoerate yaw, long period, pretty heavy damping and looks just the way it looked before. It interferes with your ability to stop on a heading because the Dutch roll gets excited quite a bit by this large, what appears to be adverse yaw of the aileron. Closed loop - this induces a rolling oscillation and a corresponding yawing oscillation and this one shows up particularly on the ILS where the yaw is fed into the flight director presentation so if you're flying bank angle primarily, but you're looking at some of the yaw response of the Dutch roll being driven by your efforts to fly the bank angle and this produces a closed-loop instability in the pilot, the flight director, and the airplane. So obviously the closed-loop damping isn't very good. The only way you can get rid of that is to reach a point where you can ease off on the aileron motion, then the Dutch roll damping is pretty heavy and the motion goes away quickly, but otherwise it will keep going indefinitely. The oscillation, you try to control with the ailerons, you hardly use the rudder. It was too complicated to control with the rudder. Couldn't figure out what to do with it very well, because of the screwed up frequency, of the low frequency of the Dutch roll and the high frequency of the pilot driving the airplane through the roll mode. It's difficult to figure out and so you don't use it at all. It was excited by the ailerons, it was easy to excite by the ailerons. Turbulence excited it by driving ϕ and requiring some δ_a to fix. δ_a then makes the oscillation. The rudder, as I stated, was not used very much. Spiral did not seem to be a factor, never noticed it spiral off.

Control Feel

The forces, the aileron seemed good; the rudder, good; elevator, good. Rudder is particulary good, I think. The aileron might be construed as being a little heavy because you have to use quite a bit of it. If it's lighter, then you excite it all the time, so I think it's good. It seems reasonable for all three. The maximum travel, never reached, so I'm unable to comment. Breakout forces seemed good on all three axes. I would not want much less breakout force on the ailerons, I like that in order to be able to set the aileron where I want it and make it stay without having to retrim the airplane every time. Same with the elevator, but I'm not sure if we couldn't stand more on the elevator.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Only by diverting attention and that effect was pronounced. The longitudinal performance wasn't as good because you had to spend too much time on the lateral-directional motion.

ILS Beam Capture

Localizer beam capture was possible but fairly difficult. You had to pay attention to it because of the sloshing about when you enter and recover from turns. Glide slope was moderately difficult because of the lousy longitudinal handling qualities, spongy response to the elevator input and the tendency to drive an overshoot, whoever made that one made a good one.

Ease of Rolling Out on Desired Heading

To roll out in a bank angle was fairly easy, not real easy, but not very difficult either. Heading, however, was moderately difficult to very difficult for accurate, precise, quick heading acquisition. Quite difficult to do that because the Dutch roll would make the airplane slosh around and you would excite the Dutch roll with the yawing moments stuck in by the ailerons trying to fix the bank angle to what you want.

ILS Beam Tracking

Small corrections on the localizer were moderately difficult because of the tendency to overshoot, this sloshing about, the difficulty in settling down right directly on a heading that you want. Glide slope and airspeed were difficult for the reasons we've talked about before where the airplane is a lousy airplane longitudinally.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections are moderately difficult for the reasons we've just been talking about and you do get a little overshoot where you tend to keep driving it in small bank angle errors and this distracts you from the longitudinal stuff.

Ability to Pick Up a Wing

The ability to pick up a wing is hard to describe. It's adequate, but excites extreme yaw motion so that this is the weakest part of the whole airplane. If the wing gets down, when you pick it up all hell breaks loose and so although the wing will come up, the fact that you excite this distressing motion at the same time makes me really consider it inadequate. So inadequate doesn't mean the wing won't come up, inadequate says bad things happen at the same time and whole process of picking the wing up is not good.

Roll Authority

The maximum roll rate, more than adequate. I don't think we need as much as we got.

Trim Changes

Trim change is small, with power. I saw no other trim change. It's easy to control.

Would Fatigue be a Significant Factor?

You fly it and the fatigue effect would not be extreme, but it's not a good airplane to fly for a long period. In rough air it would be pretty interesting because then you would find that the effect was extreme, I mean the effect would be tiring and I'd think that it would be a significant factor because you don't always have the smooth air.

Workload

Workload is moderately large in trying to puzzle out what's going on and think ahead of this airplane. So you don't have much time to pay attention to the important things such as how are you doing.

Most Objectionable Features

The most objectionable feature is this extreme sloshing about of the nose when you pick up the wing and that's pretty bad. The other thing is when you drive the bank angle with the aileron, you tend to get this closed-loop oscillation if you try to keep the bank angle exactly at some particular value. That's not good. Then the low frequency Dutch roll which comes in and makes the heading slosh about later on and you don't dare fix it with the ailerons and you can't fix it with rudder, that's not good either. And then of course there's the longitudinal characteristics which are still as poor as they ever were and this is bad. Nothing stands out as particularly good.

Turbulence Level on the Approach

Turbulence is light. The rating I could call a D. It's the same turbulence as configuration S3 but this configuration is harder to fly so the same turbulence requires more effort.

Performance of Various Segments of the Mission

How well do I perform the segments - the straight and level flying is not too good. You get busy trying to fly the poor lateral characteristics, trying to make the heading that you want and that tends to distract you from the longitudinal and if you get started on the longitudinal, then the lateral gets away, so that's not very good. Beam capture was fair, tracking the localizer was fair in spite of these poor characterisitcs, you could sit there and wobble your way down the localizer and I didn't mind this too much. If you have to pick up a wing in the middle of it, you will severely damage the approach. That is, it makes the nose go sloshing off so much that I'm not sure you could complete that approach especially if you were in close. The glide path and airspeed tracking was performed moderately well. Again, the whole configuration was poor but by just letting it oscillate its way down the localizer with the pilot driving the oscillation and just admitting that it was going to oscillate, you could do a passable job. Lining the airplane up with the runway, if you break out VFR, more or less lined up, you could keep it lined up pretty well and with pretty good assurance, yes, it would in fact stay lined up. In other words, I felt I could have landed the airplane. And if you got off, for moderate corrections, to get back lined up with the runway, you could accomplish this, given some time. The long τ_R makes it take a little time to pick the wing up and get going, for these corrections. The low Dutch roll frequency makes the airplane slosh around for longer, you have to use some rudder to try to straighten it out. You can more or less do this, so that you end up being able to make the airplane go down the runway fairly well.

Configuration Rating

The configuration - it's controllable and now probably you could get adequate performance and I felt I could land the airplane, but certainly it needs improvement and it's a hard thing to say because if I don't think about picking up the wing, then it would probably be hardly worse than a 5 and taking all things into account, I think I'd call it a 6. It's a hard one to rate because you could do the job, but it's true, you're paying quite a bit of attention. I think I would call that business of picking up the wing very objectionable, but if I had to fly it that way, I guess I would fly it as a normal thing. I think that would be pretty bad. So I think I'll call it a 6. Incorporating the longitudinal in there doesn't make any difference. And the things that make the difference or that causes the rating are what I just said. If I were to debate, I would debate whether to call it a 7 rather than a 6 on the basis of picking up the wing, not on the basis of the closed-loop flying of the airplane. I also question it in rougher air, that might have degraded it still more. I don't think it's better than a 6. As I see it, I don't think it's much worse either, but I think it could be rated worse.

Pilot B Configuration P-13 Flight No. 95

C_{n_p} = -3(BL) = +.315/rad

C_{l_β} = +5(BL) = -.086/rad

General Comments

Generally a poor model due to excessive proverse yaw which is induced due to roll.

Coordination in Turns

Initial turn in turbulence with a zero rudder, then secondary rudder was used first against the turn and then with the turn to coordinate the turn and then in steady state it required rudder with and against the turn. Accomplishing turns, if we make this a coordinated turn, would be moderate to very difficult. The reason for this is excessive proverse yaw.

Initial Response to Aileron-Only Input

Initial response to aileron input would be again excessive proverse yaw. The nose turns too fast and then as the turn is continued with aileron only, the directional oscillation is set up which has a period approximately of 10 seconds. I noted a little lateral acceleration; there was some during rapid maneuvering when making low approaches down the runway. However, this is a familiar aircraft motion, it is not a pure lateral acceleration because you get aircraft roll along with it just in controlling the aircraft.

Ease of Achieving Desired Bank Angle

Achieving desired bank angle was moderately easy and there was some tendency to overshoot the turn and that was slight.

Oscillatory Characteristics (Lateral-Directional)

Looking at the model open loop, it was of course damped, positively damped, both oscillations, laterally and longitudinally. The aircraft was excited directionally and longitudinally. The period was around 10 seconds directionally and the number of oscillations to damp to zero were not counted. Longitudinally, it looked like the period was roughly a minute which is a pretty long period. Closed-loop oscillations, lateral-directional inputs didn't seem to excite the aircraft longitudinally and conversely longitudinal disturbances didn't appear to excite the aircraft in the lateral-directional mode. Damping directionally was fair to poor and longitudinally the period seemed excessively long and damping was positive. Basic oscillations set up were due to aileron inputs in making instrument approaches. Oscillation generally was controlled with the rudder and it was difficult to control. It was a little easier to control VFR than IFR. Generally, flying instruments, it appeared to be better to stay off the rudders rather than try to make directional control inputs to damp out the directional oscillations. Oscillations were excited with the aileron and were easy to excite. Turbulence was not a factor. Generally, in the instrument flying, the rudder control was used very little. Spiral didn't seem to influence the task performance and looking at the open loop spiral stability, it appeared to be near neutral.

Control Feel

The comments haven't changed, because we haven't changed the control feel in any way or the gradient or travel or breakout forces.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control inputs didn't cause excessive lateral-directional motions.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

The lateral-directional inputs didn't cause excessive longitudinal aircraft motions.

ILS Beam Capture

ILS beam capture was moderately difficult and glide slope would be moderately difficult. Proverse yaw was the contributing factor to this.

Ease of Rolling Out on Desired Heading

VFR, looking at general headings and section lines, would be considered easy just to select rollout on a general heading. Headings IFR were very difficult to control when using the heading marker on the HSI. With using the flight director, the heading control was moderately difficult. Bank angle control would be moderately difficult.

ILS Beam Tracking

ILS beam tracking -- localizer was moderately difficult, glide slope moderately difficult and airspeed the same. Of course the excessive proverse yaw due to aileron input is the determining factor on this.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections were moderately easy and also I add here that small bank angle corrections were easier than large bank angle corrections. In attempting to make large bank angle corrections, it excited the airplane directionally so that lateral PIO usually resulted.

Ability to Pick Up a Wing

Ability to pick up a wing would be considered adequate.

Roll Authority

Under the ILS approach, roll authority would be barely adequate.

Trim Changes

Trim changes normal with airspeed and power changes and the compensation for trim control was generally easy.

Would Fatigue be a Significant Factor?

Fatigue factor at the end of a long mission I think would considerably influence the safety of an approach with this model. I think it would be a hazardous approach.

Workload

The workload would be moderate to large, favoring the large, under instrument flying conditions.

Most Objectionable Features

The most objectionable feature which has already been pointed out for this model, is the excessive proverse yaw due to roll.

Turbulence Level on the Approach

Turbulence rating would be an "A".

Performance of Various Segments of the Mission

Mission performance for this model would be below average.

Configuration Rating

Configuration rating, I would consider it a 7.

Pilot A | Configuration P-14 | Flight No. 87

$C_{l_\beta} = +5(BL) = -.086/\text{rad}$

$C_{n_{\delta_a}} = +3(BL) = -.0345/\text{rad}$

General Comments

It was not a bad airplane. If you used a lot of aileron, you got substantial lateral acceleration, but very little sideslip. The sideslip indicator showed very little sideslip. You did, however, excite some rolling motion, and in the process of controlling it, tended to oscillate in roll. Furthermore, if you tried to turn to a heading and stop there, it was very difficult to stop on a heading. You would oscillate and come out on some other heading needing another correction from there. The longitudinal motion is hard to fly, requires quite a lot of care to control airspeed and rate of climb. The control of the pitch attitude feels sort of spongy. Not the feel system itself, but it's hard to make the pitch attitude stop right where you want it. You tend to get a small oscillation of 1 or 2 overshoots which are driven by the pilot. The open-loop airplane is well damped.

Coordination in Turns

It was possible to use some initial rudder with the aileron to aid in decreasing lateral acceleration but wasn't very feasible. It's possible but it doesn't work very well. Secondary rudder - there wasn't any and the steady state rudder - there wasn't any. I didn't use the rudder very much. Ease in accomplishing turns -- it was moderately difficult because of time to roll the airplane up and get it to the desired angle, at what apparently is the Dutch roll frequency. The pilot tends to increase this oscillation by trying to stop it and it's connected with the sloshing about of the airplane due to the aileron input.

Initial Response to Aileron-Only Input

The yawing motion at the start of the turn - the lateral acceleration is quite pronounced. The nose actually turned a little bit the wrong way first. The lateral acceleration is large enough to be noticed and it's a disadvantage.

Ease of Achieving Desired Bank Angle

It is moderately difficult to achieve a desired bank angle quickly and accurately. You tend to oscillate in roll about the bank angle. The overshoot is slight to moderate; it's small but it's still there, it affects the pilot's ability to make the roll stop where desired.

Oscillatory Characteristics (Lateral-Directional)

Looking at the Dutch roll; it's a moderate roll to yaw ratio, rather flat Dutch roll and well damped, really quite well damped for the Dutch roll. Closed loop gives moderate or small roll oscillation and small to moderate oscillation in heading, apparently driven by the pilot. The damping open loop is good. The closed loop damping isn't good enough. The oscillation was controlled with the aileron and it was between moderately easy and difficult. I did not find the rudder particularly helpful. Maybe I could learn to use the rudder more. The oscillation was excited by the aileron inputs and it was pretty easy to excite. The turbulence excited it and it was easy. I never noticed the spiral. I did not seem to be doing anything special to make the airplane behave as far as the spiral was concerned.

Control Feel

The forces are heavy on the aileron and elevator and good on the rudder. However, we purposely picked these heavy forces to make it hard to accidentally disturb the airplane. We found that light forces induced the pilot to just kick the airplane all around getting these large lateral accelerations. So although these forces are heavy, they are acceptable. The travel is reasonable for all. The breakout forces seemed okay in the aileron and rudder and elevator. I wouldn't mind having a little more breakout force on the aileron.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Perhaps. It is conceivable that lateral-directional inputs cause me to excite this longitudinal motion and longitudinal motion is not easy to control in this airplane. That's the worst part of the airplane.

ILS Beam Capture

The localizer was quite easy to capture. The glide slope was not as easy to capture because of the difficulty in controlling the pitch angle exactly. The localizer capture with the flight director was relatively easy.

Ease of Rolling Out on Desired Heading

To roll to a bank angle was somewhere between moderately difficult and easy. You could get to the gross bank angle that you wanted quite easily but it was hard to settle down exactly, hard to make small bank angle corrections. The heading IFR was moderately difficult to stop. The heading VFR was fairly easy. I had no difficulty in lining up with the runway. This oscillation driven by the pilot in bank angle when trying to stop at a given bank angle made it difficult and similarly for VFR, the difficulty was the oscillation in heading angle when trying to stop on a given heading.

ILS Beam Tracking

The ability to make small corrections on the localizer was somewhere between easy and moderately difficult. The glide slope - somewhere between easy and moderately difficult and more nearly moderately difficult because of the difficulty in controlling the airspeed and the pitch angle at the same time. Airspeed was moderately difficult. It's hard to make this airplane fly at a given airspeed and the speed changes seem to be surprisingly rapid. Ability to make small bank angle corrections was moderately difficult due to the oscillation apparently driven by the pilot while trying to correct the bank angle.

Ability to Make Small Bank Angle Corrections

The ability to pick up the wing is adequate and roll authority is adequate or more. Trim changes with power, elevator trim change with power, and I saw no lateral trim changes.

Would Fatigue be a Significant Factor?

It's not an easy airplane if I had to fly it closely. If I could fly it in what I would call the normal cruise looseness, I don't think it would be particularly bad. The high forces would be a nuisance but better than continually disturbing the airplane.

Workload

I consider my workload to be moderate.

Most Objectionable Features

The most objectionable feature is the lateral acceleration at the cockpit when applying some aileron which seems to induce the pilot to disturb other modes. Also you tend to roll the airplane about the desired bank angle a small amount at a frequency higher than Dutch roll. The second objectionable feature is the difficulty in controlling the pitch angle quickly and promptly to the desired spot. You always overshoot.

Turbulence Level on the Approach

Turbulence level moderate, call it about "E" on the scale.

Performance of Various Segments of the Mission

I performed the various segments only fairly well, not as well as they should be performed, especially the glide path control. The localizer control was performed fairly well. Capture fairly well, not perfect. The flight path control and airspeed control not very well performed. They should be better and need to be better.

Configuration Rating

The configuration is controllable talking about the lateral-directional. As far as the longitudinal motion is concerned, you can not do an adequate job with this airplane with a tolerable pilot workload. If rating the longitudinal motion, would call it a 7. However, accepting the longitudinal motion for what it is and looking at the lateral-directional, it is satisfactory, you can do the job. The deficiencies warrant improvement. It's moderately objectionable and requires considerable compensation to outfox this little roll oscillation and this yawing oscillation. I'll give it a rating of 5.

Pilot C — Configuration P-14 — Flight No. 100

C_{l_β} = +5(BL) = -.086/rad
$C_{n_{\delta_a}}$ = +3(BL) = -.0345/rad

General Comments

None.

Coordination in Turns

Coordination in turns is pretty good. I'm not using any rudder at all, either entering or steady state. Ease in accomplishing turns is easy. Factors contributing to this choice is that it's fairly well coordinated and we'll be talking a little bit about the $C_{n_{\delta_a}}$ later on. It's present but it's not a problem, particularly in making heading changes or bank angle changes.

Initial Response to Aileron-Only Input

The yawing motion at the start of the turn is just about right. No appreciable nose hangup on turn entry. If you make a fairly smart roll entry, you do notice an a_y so I'll say a_y is perceptible but not particularly objectionable from the pilot's point of view. It might be from the bombardier's.

Ease of Achieving Desired Bank Angle

Achieving desired bank angle is easy. Factors that contributed to this choice is that we have nice force gradient, good coordination, essentially a zero spiral and a little positive C_{l_β} which may or may not be helping it. At any rate, it's just very easy to control bank angle. Overshoot tendency of bank angle in the roll mode is none to slight if you are distracted only.

Oscillatory Characteristics (Lateral-Directional)

Oscillatory characteristics are not perceptible. The magnitude is small to negligible open loop and closed loop in both roll and yaw. It has good damping in the directional oscillation modes. I'd say it's adequate or more than adequate. The oscillation doesn't exist so controlling it is not applicable. Tried to excite it with rudder inputs and with aileron and they did not excite it. We had no turbulence so can't say for that. The spiral mode, as I mentioned was essentially neutral.

Control Feel

Control feel -- was good in all three axes. The travel associated with these forces was reasonable. We did not look at full travel because of our previous experience with the system indicating we would probably be exceeding the limitations. So I was unaware of the extent of travel and it did appear unimportant. Breakout forces were good and not appreciable so they were essentially nonexistent.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Longitudinal control inputs did not excite lateral-directional motions.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral-directional inputs did not excite longitudinal airplane motions.

ILS Beam Capture

ILS beam capture was easy and glide slope was easy.

Ease of Rolling Out on Desired Heading

Rolling out on a desired heading was just fine both VFR and IFR. The bank angle control was good. The factors were mentioned above, being essentially a nice force gradient, good coordinated controls and no proverse or adverse yaw and essentially zero spiral. I think that the good centering and the lack of a deadband or breakout forces is also contributory. I'm saying on all these that I didn't notice any breakout force and I'm not a breakout force measuring expert. I can't say but what you might have a little breakout force there but if you do, it's just right. And that's true, not just with respect to today's configurations but the others that we've looked at the last two days.

ILS Beam Tracking

ILS beam tracking ability is easy both in localizer and glide slope and airspeed was also fairly easy. We seem to have a little trouble getting the throttles matched so that we're really in level flight at an indicated 55% thrust on engine No. 1 or on glide slope at 10%. Frequently, on glide slope we're down to zero indicated thrust and we're just playing the throttle there necessary to control airspeed. Even that way though, it's not particularly difficult, once you get used to it.

Ability to Make Small Bank Angle Corrections

Ability to make small bank angle corrections was easy as stated above, and for the same reasons.

Ability to Pick Up a Wing

Ability to pick up a wing is more than adequate.

Roll Authority

Roll authority is adequate or more.

Trim Changes

There are no perceptible trim changes due to power, speed, or attitude so I'll put small to nil. Ability to compensate is not applicable because it's not a problem.

Would Fatigue be a Significant Factor?

In cruising flight I think we have excellent control characteristics. Considerable length of time would have no fatiguing effect on the pilot.

Workload

Workload is small.

Most Objectionable Features

The most objectionable feature is either $C_{n_{\delta_a}}$ or C_{n_p}. I don't know which but at any rate, one of those is yielding slight a_y on roll entry. All the other features, I think, are particularly good. It's a well harmonized airplane with that minor complaint.

Turbulence Level on the Approach

The turbulence level was "A" and there was essentially none.

Performance of Various Segments of the Mission

I think the performance of the various mission segments was pretty good.

Configuration Rating

The configuration rating on this airplane overall is still pretty good. I think that I'd say it's about a 2.5 and the adverse comment I've mentioned before is this slight a_y upon a smart turn entry. Still a very good airplane.

Pilot A | Configuration P-16 | Flight No. 115

C_{l_β} = +5(BL) = -.086/rad
$C_{n_{\delta_a}}$ = +6(BL) = -.069/rad

General Comments

It's not a good configuration, it's barely flyable for some purposes. You can make an ILS fairly well, better than with the last configuration, however, the sloshing sideways across the runway seemed worse than the last configuration and I do rate this as having some importance, so it's a poorer airplane, not a good one to fly, but you could get it down in ILS and you could make a landing with it, however, your security as you are lining up on the runway is not good. You don't feel that you could say, I've got it made, I could make that thing go down the runway, because any roll correction will make the airplane slide sideways off the runway.

Coordination in Turns

Initial rudder, I could not figure out a system which would really make it stay coordinated. It was too difficult. You crank in some aileron and the time history of the rudder which goes first one way, the ball which goes first one way and then the other was too difficult so I did not really figure out a time history of rudder deflection that would make sense that I could do easily. So you use a little rudder to start with and I don't know which way and then use a fair amount of secondary rudder. I don't know which way to call it so it's really to make a ψ or r match the bank angle that's what you really do. The same with the initial rudder, doesn't take as much but you do it to make ψ or r look right. So this works fine VFR; IFR no hope except the aileron only motion and use some δ_r to damp Dutch roll toward end of maneuver. This is what was actually happening. Nothing in the steady state turns. Turns were depending on what you define them. The IFR turns were moderately easy, and the VFR turns I consider moderately difficult due to this sloshing about which was really pretty lousy.

Initial Response to Aileron-Only Input

The initial response in turns, is wrong way first then sloshes wildly, I don't know which way really. I sorted it out but it doesn't stick with me. In other words it's not something that you sort out, understand, and say oh, I know what to do with this. You would have to sort it out each time. That's why you have to close the loop on something that you can close the loop on, which in this case was to make the motion of the nose look right in the turn. In other words, to follow the bank angle the way you ought to, as you roll out of bank angle use whatever rudder necessary to damp the Dutch roll and make the nose behave properly. Lateral acceleration was moderate, objectionable, but not as bad as some we have seen.

Ease of Achieving Desired Bank Angle

Achieving a desired bank angle was moderately easy, or moderately difficult depending on how you were trying to do it but it could be done. You do overshoot in ϕ because you tend to drive the airplane. I didn't see as much overshoot as in the previous configuration.

Oscillatory Characteristics (Lateral-Directional)

The oscillatory characteristics, open loop, the same Dutch roll as usual. Small roll, moderate yaw, long period, rather heavy damping. Closed loop you've got a small oscillation in roll which led to a small oscillation in yaw, but this was not as bad as before. You didn't make it continue as much as before. The oscillation is not heavy enough to make the close-loop instability go away. I would like to see more damping with the Dutch roll but even so it is pretty heavy damping. The closed-loop oscillation is controlled with the aileron, it is hard and the rudder you use to damp the Dutch roll at end of roll correction. That's roll angle correction not roll rate correction. The oscillation was excited primarily by the ailerons, you could excite it with the rudder but why would you do that. Turbulence did not excite it much at all. The spiral did not appear to be a factor, never noticed it one way or the other. Certainly didn't notice it spiralling off.

Control Feel

The forces seemed reasonable to me. I wouldn't have known which way to go to make them better. The ailerons are fairly heavy but I know if we make them light I would overcontrol even worse so I am not complaining. Gradient seemed reasonable in all three axes. Maximum travel was never reached so I have no comment on it. Breakout forces seemed pretty good in all three axes, I like them the way they are.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

The usual comment that lateral-directional workload interfered with time available for longitudinal.

ILS Beam Capture

ILS beam capture - localizer, actually was moderately easy. Even under some difficult circumstances I could do it. Using the rudder to damp out the Dutch roll toward the end of your roll command, I had no difficulty. I overshot the localizer beam one time, I was in fairly close, made a rather prompt turn back in again, I had no difficulty settling right down on the localizer and staying there. So I thought that was pretty good. Glide slope was moderately difficult as usual because of the spongy indefinite longitudinal characteristics of this airplane.

Ease of Rolling Out on Desired Heading

Rolling out on a desired bank angle was fairly easy. Not really easy, but fairly easy. All this sideslip that is excited and this yawing motion doesn't do an awful lot to the roll as it doesn't cross couple back into the rolling motion so you can get along with it better than you might think. You excite this wild sloshing motion, but it doesn't stop you from ending up at the right bank angle so that wasn't so bad. Heading IFR I think is very difficult to settle down on because of the low frequency Dutch roll and the fact that everytime you put in some aileron to fix the heading you excite the Dutch roll and so you are in just as much trouble as you were to start with. So I call that very difficult. Moderately difficult for VFR where you have a better idea of rates and so on.

ILS Beam Tracking

Localizer beam tracking was moderately easy. Better than your first reaction to roll corrections would lead you to believe, because you just set the bank angle and take the mean of whatever little oscillation you pick up and you don't put in such big oscillations as to really excite this terrible Dutch roll anyway. Glide slope and airspeed moderately difficult for the reasons we discussed before.

Ability to Make Small Bank Angle Corrections

Moderately easy to make small bank angle corrections. Because the sloshing motion did not feed back and affect the roll motion very much, you just selected the mean of your small oscillation, pilot-induced oscillations in roll. I really didn't find it too difficult.

Ability to Pick Up a Wing

The ability to pick up a wing, that's poor. Okay, roll rate, but large sloshing yaw motion and that's pretty bad so I think I call it inadequate, not because of the roll rate, but because the total motion is inadequate, I don't really like that. It's not possible to develop rudder that really fixes it. You could do something to help it with the rudder but it still was pretty poor. However, you could pick up the wing. So I don't know how to answer that question. I'll call it inadequate in the sense that it's not what I want but it's adequate in the sense that I could pick up the wing.

Roll Authority

You had more roll rate that you needed.

Trim Changes

Small trim change with power, no other trim change, was easy to correct.

Would Fatigue be a Significant Factor?

Moderate contributor to fatigue. Not as bad as the preceding configuration which was oscillating round and round with pilot inducement would be bad, but still not good either.

Workload

Workload is large, you have to pay attention to what you are doing. If you have to correct for flight path corrections going down the runway, that is, to make the airplane stay over the runway, you've got a problem.

Most Objectionable Features

The most objectionable feature is the tendency to slide sideways over the runway with aileron input and the large yaw motion, I am really considering that r, I don't care what the sideslip does, and the lateral acceleration at the cockpit which really isn't that bad at this configuration and the longitudinal characteristics which are slow-also the slow Dutch roll.

Turbulence Level on the Approach

Turbulence level was light. On our rating scale I would call it a D. With a better configuration, the turbulence rating would be more toward A, I wouldn't say that it would be an A, but it would be more in that direction.

Performance of Various Segments of the Mission

Holding a heading on downwind was not done very well. It was hard to hold a heading, it was hard to make heading corrections due to the low frequency Dutch roll and the fact that every time you put in some aileron to roll to a new heading you excite the Dutch roll and don't end up at the heading you want. The capture of the localizer was done fairly well, just select the mean of the bank angle and wait and sooner or later the thing would come out all right. The tracking of small corrections on the localizer also, not bad because, you accept the mean, you don't put in big inputs so don't excite a whole lot of this Dutch roll. The glide path was tracked fairly well, considering that this is a poor airplane longitudinally and hard to fly. Right down to the bottom of the ILS getting close to minimums, you could still do a reasonably good job of flying the localizer using the ailerons only primarily and a little bit of rudder at the end to help damp out the Dutch roll. The lineup with the runway, you could line it up fairly well as long you start lined up, or as long as you had enough time to get yourself in position and line up and recover from the bank angle very slowly, but you didn't have a good feeling of security in these circumstances because if you had to make any corrections with the aileron the airplane would drift sideways, travel sideways, not just wind drift across the runway and I didn't like that very much nor did I think that was very safe. I wouldn't want it to touch down right when that was going on, and you might have to make such correction, so I didn't like that part. Picking up wings also I didn't like the sloshing around of the airplane. It was wild sloshing, pretty bad.

Configuration Rating

The rating again is a hard one. Is it controllable, adequate performance? Again this is a difficult one, you could fly down the ILS, you could get lined up. It seemed pretty good, except if you had to make a correction at the bottom in bank angle you were in trouble with it sliding sideways off the runway. If a wing went down you were trouble with the extreme sloshing around of the airplane as you picked it up. So it is hard for me to tell how to call it. Looking at the airplane as if all is going well requires some work. You have to pay quite a lot of attention, it would be like a 5 or 6, but counting these necessities to sometimes having to pick up a wing, to sometime make corrections on the runway, and not liking this, because I don't like this travelling sideways across the runway following an aileron correction, I'll call it a 7. It isn't just that I don't like it. You can't make the airplane go down the runway if you have to fix it with the aileron and using the rudder won't help then. Nothing you can do about it. It's going to go sideways across the runway. I don't quite see what would make an airplane do this. So I guess I'll call it a 7 and I just described what made the airplane come out that way. The longitudinal feature was not the determining feature in this rating. It was the lateral-directional, primarily the sliding sideways across the runway and the wild oscillation, the wild yawing motion, following an attempt to use aileron to pick up the wing. The ILS could actually be done fairly well.

Pilot A Configuration S-1 Flight No. 89

$C_{\ell_r} = +2(BL) = +.42/rad$

General Comments

The nose sloshed around with the roll rate but this didn't really hurt you very much provided you knew what was going on and you could then use rudder to help you and you could learn to use the rudder. What you could not do was correct it very nicely for errors put in by gusts. Also, it was not easy to line up with the runway so it wasn't really very good.

Coordination in Turns

You use initial rudder with the turn in a relatively small amount and then secondary you have to use a large amount of rudder with the turn. The steady state rudder seemed close to zero. I thought the turns were easy if slow, and quite difficult if rapid entry and the factor that contributed was this sloshing about of the nose.

Initial Response to Aileron-Only Input

Yawing motion at the start of the turn; at the very start it hangs up only a little but then soon it turns the wrong way first and by quite a lot, and you must use a lot of rudder then and it's hard to do, and I say a lot of rudder. Lateral-acceleration was not particularly high and it was relatively smooth.

Ease of Achieving Desired Bank Angle

To achieve a bank angle was moderately easy both VFR and IFR, easier VFR. It would have been easier if it had been a more prompt start of the roll. Of course, it would have been easier if it didn't have this sloshing about feeling. Overshoot in bank is slight not particularly affected by this large sloshing about.

Oscillatory Characteristics (Lateral-Directional)

Open loop -- not much roll, quite a bit of yaw. Large damping and rather long period which becomes troublesome. Closed loop oscillation yaw due to the difficulty in stopping this turn where you want it. The oscillation in roll is actually small. These closed loop oscillations are not sufficiently well damped. You go through several cycles to get rid of them. The oscillation was controlled with aileron and rudder and not easy. Oscillation was excited primarily by the aileron and of course you could excite it with the rudder. Turbulence would excite it but not too much. You'd use the aileron primarily to control oscillation but you did use the rudder especially for large corrections and especially VFR. Spiral did not seem to be a factor.

Control Feel

Aileron forces seemed good but on the heavy side. Rudder seemed good but on the heavy side because now you use so much rudder. Elevator seemed good but on the heavy side because now the disturbances in aileron made you do a poorer job with the pitch control and so you were using more elevator than you did before. The gradient in aileron seemed reasonable enough, rudder seemed reasonable enough, elevator seemed reasonable. The maximum travel seemed oaky for all of them. Breakout forces seemed okay on all of them.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

So far as I know, no.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Yes. Trying to correct for this lousy lateral-directional characteristics. I think caused some pitching motion and I know it interfered with your control of the pitching motion and was a significant loss.

ILS Beam Capture

Localizer was fairly good. The sloshing about required some rudder to make the heading come out where you wanted it to but the flight director was quite easy to fly in bank angle. This sloshing didn't affect your control of the bank angle very much. Glide slope was moderately difficult because first of all it's a difficult airplane in pitch. Second, the disturbances we were putting in all the time by the aileron certainly complicated your life in controlling the glide slope and the airspeed.

Ease of Rolling Out on Desired Heading

Bank angle is relatively easy to stop. There was a little oscillation in bank angle but it was not particularly bad. The heading IFR was moderately difficult if the inputs were put in by the pilot and considerably difficult if they were disturbed by rough air. The difference was that if it was disturbed by the pilot, you know what to expect and if it was disturbed by rough air, you didn't. VFR, I would call it moderately difficult to control the heading, taking lots of rudder, you had to learn put in rudder proportional to roll rate, not bank angle, and this was particularly difficult on the recovery, but it could be learned and was not more than moderately difficult.

ILS Beam Tracking

Localizer was fairly easy to track. Glide slope was moderately difficult. Airspeed was moderately difficult to very difficult because of the difficulty in pitch. I think this was exaggerated by the lateral-directional characteristics which left you less time to play with these things. I certainly had more trouble with the airspeed on this configuration.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections are moderately easy with this slight overshoot in roll, this long time to get started but the sloshing about had an effect on it but not a very great effect.

Ability to Pick Up a Wing

Ability to pick up a wing is adequate but you need a lot of rudder.

Roll Authority

The roll authority seems okay.

Trim Changes

Trim change with power setting did not seem to be too terrible. The ability to compensate for the trim change was pretty easy.

Would Fatigue be a Significant Factor?

I did not find it troublesome. I don't think it would bother me for any length of time.

Workload

The workload was moderate. It becomes large for large corrections as VFR, runway alignment.

Turbulence Level on the Approach

Turbulence level seems light. More effort was required and I would call the effects light/moderate so I would call it light, "D".

Performance of Various Segments of the Mission

ILS capture was fair. Localizer capture was fair. Altitude control was relatively poor. Airspeed control was relatively poor. Capture of the glide path was relatively poor. The tracking of the localizer inbound was relatively good. Performance of the offset maneuver was fair but not as good a degree of assurance that I was really going to make it, so that although the performance was pretty good, I didn't like it as well. All in all, it wasn't a terrible one except that my longitudinal control, speed and flight path, I don't think was very good and I think this was deteriorating because of the poor lateral-directional characteristics.

Configuration Rating

Adequate performance-just barely and I'm not even sure it should be rated that good but I think I would rate it a 6. The thing that makes me worry is that my longitudinal performance became poor and so then I would call it a 7. Lateral-directional alone would have been a 6 but the influence of the lateral-directional made the longitudinal poor so overall lateral plus longitudinal was poor so I'll rate it a 7 for the whole airplane.

Pilot A Configuration S-1 Flight No. 112
$C_{\ell_r} = +2(BL) = +.42/\text{rad}$

General Comments

This is a good configuration, first good one I can remember having. Laterally it's a satisfactory airplane. Longitudinally, it's not really a good airplane at all. It still has all the lousy longitudinal characteristics we've been talking about, but the lateral-directional has gotten good.

Coordination in Turns

Used very little rudder, may have used a little bit with the turn and no steady state rudder, no secondary rudder. Easy to accomplish the turn. You could bank to the bank angle and the airplane would stop there. You didn't have much lateral acceleration. You did not excite the Dutch roll much in doing this and all these things were helpful.

Initial Response to Aileron-Only Input

The initial response, I don't know what it does, I think the nose hangs up a little bit, but not very much and the lateral acceleration is minimum, and quite acceptable.

Ease of Achieving Desired Bank Angle

Easy to achieve the desired bank angle, better if the roll mode time constant were a little shorter, there's a slight pause as you get going. You didn't see much overshoot in bank angle if there was any.

Oscillatory Characteristics (Lateral-Directional)

Open loop - same as usual. Small roll, moderate yaw, longish period, rather heavy damping of the open loop motion. Closed loop - we didn't see any oscillatory characteristics, so that was pretty good. You almost didn't have to control it and if you did, why you use some aileron to control it. The motion was excited partly by aileron and partly by turbulence, turbulence exciting the open loop Dutch roll, but not closed loop. Hardly used the rudder, I don't know whether I used it or not. Spiral did not seem to be a factor. No notice from me of any troubles with the spiral.

Control Feel

The forces, aileron seemed reasonable, the rudder reasonable, elevator reasonable, gradient was reasonable for all of them. I didn't notice the maximum travel. The breakout forces were good for all three surfaces.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Didn't notice any, or minimal interference between making lateral corrections and longitudinal corrections.

ILS Beam Capture

Localizer seemed reasonably easy to me. I made one that was rather difficult and still was able to do it, intercepted in close and had to rack the airplane around and was able to do this. Glide slope - moderately difficult because of the poor pitch control, sloshy, imprecise, soft pitch control tending to overshoot, drive an oscillation to overshoot in pitch when trying to acquire a given pitch angle.

Ease of Rolling Out on Desired Heading

Bank angle - seemed pretty easy. Well, the IFR heading for small corrections, the Dutch roll still interferes, the frequency is still long. So it isn't dead easy, but it's a lot easier than it's been and it was pretty good.

ILS Beam Tracking

The beam tracking on the localizer I thought was fairly easy. Glide slope - moderately difficult because of the poor pitch correction. Airspeed - moderately difficult because of the poor pitch angle control in this airplane.

Ability to Make Small Bank Angle Corrections

I call it easy because of this lack of overshoot with the closed loop. Feel it would be easier if we didn't have this problem of the slightly long response time, but that was not a serious interference at all.

Ability to Pick Up a Wing

The ability to pick up a wing was more than adequate, I thought it was good. I liked it. I think I'll just call it adequate.

Roll Authority

The roll authority was adequate or more.

Trim Changes

Trim change - small - with power, no other trim change, easy to compensate.

Would Fatigue be a Significant Factor?

No, I do not think fatigue would have bothered me, I'm talking about the lateral-directional. I think it would be a good airplane. Longitudinally, I don't like it.

Workload

The workload is moderate, it would have been better if I had a better longitudinal airplane.

Most Objectionable Features

The most objectionable feature is the longitudinal characteristics and I won't go on about those, we've been through it all before. And the lateral-directional - it really was a pretty good airplane. There wasn't too much to object to about it. The slightly long roll mode time constant, or whatever makes it seem long, was the worst thing about it. So it takes a little time to get the motions started after you call for some aileron.

Turbulence Level on the Approach

Turbulence level was light, we called it D, it wasn't any different.

Performance of Various Segments of the Mission

Thought I performed this segment fairly well, quite good, especially all the things that required the lateral-directional motion. Including the moving from the edge to the side to the center of the runway, it felt like it was pretty good. I have no doubt that I could fly it down the runway and land it as far as the lateral-directional is concerned.

Configuration Rating

For the overall airplane, I'd call it a 5. But the lateral-directional I'll call a 3 and the thing that made it a 3 was the fact that it had pretty good damping in the Dutch roll, you could roll it to pick up a wing and stop the bank angle pretty much where you wanted, you did not get this large lateral acceleration. It was not a terrible airplane to fly at all. I would like to see higher frequencies of the Dutch roll so that you could make the airplane stop in heading where you wanted it quicker. I would like to see the roll mode time constant a little shorter, but I wouldn't really complain if they never did fix them, both of them seemed all right to me.

Pilot B Configuration S-1 Flight No. 94

$C_{\ell_r} = +2(\text{BL}) = +.42/\text{rad}$

General Comments

None.

Coordination in Turns

I initially used zero rudder and then tried to back up using rudder both with and against the turns to coordinate the turn, and the same thing in steady state turn, I tried to use coordinated rudder and had to use rudder both with and against, small to moderate amounts. Accomplishing the turn was moderately difficult. It's easy to make a turn, just turn from one heading to another, one direction to another. However, a coordinated turn is different. To make a good coordinated turn and roll out on an exact heading is difficult.

Initial Response to Aileron-Only Input

Initial response to aileron only input (had adverse yaw) so the nose would essentially go the wrong way first about 5° sideslip. I didn't time it but it seemed to hang there for four or five seconds, maybe three to four seconds before it started turning around the other way. No lateral acceleration.

Ease of Achieving Desired Bank Angle

To achieve desired bank angle, -- I'd say was moderately difficult. Trying to roll out exactly on bank angles as I picked them wasn't as easy as it should have been. Actually didn't tend to overshoot the bank angle, I tend to undershoot it just a little bit.

Oscillatory Characteristics (Lateral-Directional)

Open loop characteristics -- there were oscillations, of course, mostly in yaw - moderate oscillations. Using a rudder kick, I had a period again of about 8 to 10 seconds and damping in 5 or 6 cycles. Longitudinally, still unable to get a real good cycle longitudinally. It's positive stability but towards neutral direction. Very little if any roll due to sideslip and again, significant yaw due to roll. Closed loop, of course, initiating turns, the nose tended to go in the wrong direction, adverse yaw first to a moderate amount. Damping laterally is fair. Longitudinally is difficult to determine because of the apparent tendency towards neutral stability longitudinally. Basic oscillations were controlled with the rudder because most oscillations were directional rather than longitudinal. Oscillation was excited again primarily with the aileron input and turbulence may have been contributing but it's difficult to tell really what significance turbulence had. Initially I tried to make turns with aileron only. Then I tried to coordinate the turns and this required use of both rudders in trying to coordinate the turn, that is, rudder with and against the direction of turn. Spiral stability not really noted.

Control Feel

Everything's too heavy in force, gradient, travel, breakout.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

I can't notice that longitudinal inputs excite the airplane in the lateral-directional mode necessarily. And, of course, lateral-directional causes the aircraft to go into more of a Dutch roll mode so that directional and lateral inputs do excite the aircraft.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

No comment.

ILS Beam Capture

ILS beam capture was moderately difficult on the localizer and the glide slope. Again, in trying to finely control a heading on instruments, tend to get in a lateral PIO about the heading.

Ease of Rolling Out on Desired Heading

First, visually rolling out on just general section line headings, VFR, wasn't too difficult. If you tried to roll out on exact headings using the heading marker on the HSI, it was very difficult and using the bank steering bar was moderately difficult. Bank angle is moderately difficult. Again the factors are lateral PIO that is set up just using the heading marker, using the flight director was easier.

ILS Beam Tracking

ILS beam tracking on the localizer and glide slope would be moderately difficult.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections were moderately difficult, easier than large bank angle corrections. You tend to get into a lateral PIO using the flight director.

Ability to Pick Up a Wing

Ability to pick up a wing was adequate.

Roll Authority

Roll authority -- was barely adequate but in trying to look at maximum roll rate I got a system dump.

Trim Changes

Trim changes, nothing abnormal with the change in airspeed and power.

Would Fatigue be a Significant Factor?

I think at the completion of a long mission making an instrument approach under minimum weather conditions would be difficult.

Workload

I would consider the workload here moderate to large.

Most Objectionable Features

The most objectionable feature again is the adverse yaw which would cause the tendency to get in a lateral PIO if you're trying to fly an exact heading without using the flight director.

Turbulence Level on the Approach

Turbulence again I would rate as about a "D".

Performance of Various Segments of the Mission

Mission performance would be an average minus.

Configuration Rating

Configuration rating, I would call it about a 7.

Pilot A Configuration S-2 Flight No. 88

C_{l_r} = +3(BL) = +.63/rad

General Comments

It's basically a pretty good configuration and with the lighter forces, it's better than it was yesterday [flight 87]. It has quite nearly the damping of the Dutch roll as yesterday, moderate roll to yaw ratio, not much kicking around due to aileron disturbances, very little lateral acceleration due to aileron disturbances, fairly easy to line up with the runway, not so easy to establish a heading precisely for the IFR heading holding task.

Coordination in Turns

Initial rudder used is with the turn and you use a moderate amount if you really want to do a good job and a small amount if you don't care very much. No secondary rudder. No steady state rudder. The ease in accomplishing turns is between easy and moderately difficult. You tend to overshoot a little in the bank angle. It's not easy to stop the heading right where you want it. The airplane has somewhat of a wallowy feeling but all things considered, not too bad.

Initial Response to Aileron-Only Input

The yawing motion at the start of the turn is about right. Nose hangs up a little but it's not bad. This condition persists for something over a second, but not an awful long time. It's not bad and for many turns you don't attempt to do any coordination. However, if you really want the nose to move around to where you want it, then you do use rudder along with the aileron to force the nose to get under way and make it move. Lateral acceleration is small, acceptable, no problem in this configuration.

Ease of Achieving Desired Bank Angle

The ease of achieving a desired bank angle is moderately easy. You tend to overshoot a bit in roll and then roll back again. The overshoot tendency is there. It's slight to moderate. It's not disabling. It's not a terrible characteristic but it's there.

Oscillatory Characteristics (Lateral-Directional)

Open loop--it's small roll, moderate yaw and the damping is pretty heavy for the Dutch roll. If you had damping this heavy you would not normally complain although it did give trouble in establishing a heading and setting on the heading and so maybe we need still more damping in order to accomplish that. The period is rather long and that adds to the difficulty in stopping on a heading. Closed loop -- you get a small oscillation in yaw which I think is the open-loop Dutch roll showing, small to moderate oscillation in yaw, enough to notice. The oscillation was controlled by using the aileron, moderately easy to control. You use some rudder. Aileron motion excited it. Rudder motion excited it and turbulence excited it. I used both the controls but I used the aileron primarily and the rudder only to help initially in the turn. I did notice the airplane spiral, but did not consider it bad. I wouldn't down the airplane for that.

Control Feel

The aileron forces are heavy but we made them heavy on purpose to keep from inadvertently disturbing it and I still stick with that decision. We have investigated the forces and changed them, made them lighter. They're still too heavy but that's where I want them. And the same is true of the elevator. When I lightened up the elevator force, I found I was inadvertently disturbing the airplane again. Rudder seemed okay. The gradient for the aileron is reasonable. The rudder seems reasonable and the elevator seems reasonable. The maximum travel for the aileron was okay, for the rudder okay although I never hit maximum rudder and the elevator also seemed okay. Breakout forces for the aileron seemed good, for the rudder they seemed good. The elevator - I asked for and got a slightly higher level of friction and this improved the airplane as far as I was concerned. It diminished the tendency to inadvertently have the control column moving all the time.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

I did not think longitudinal motions disturbed the airplane.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Lateral motions do disturb the elevator. It's awfully easy to get this airplane disturbed in pitch. It's not a nice airplane in pitch. This effect is not severe but it is noticeable.

ILS Beam Capture

Localizer capture was pretty easy. Glide slope was moderately difficult to get the airspeed and the pitch angle and the power and everything all set at once. It was not easy. The small oscillation in roll influences your ability to capture the localizer but not much when you have such a good thing as a flight director to work with.

Ease of Rolling Out on Desired Heading

To roll out on heading VFR, using rudder is necessary. It was pretty easy. I could fly it down the runway with good alignment with the runway. In IFR, you saw a pronounced tendency to wander a bit when you tried to make small corrections in heading and I would call it moderately difficult to establish a good heading and hold it. Bank angle for the IFR task I'd call easy but I do have this reservation that it took some time to get going. The pilot tended to make the bank angle overshoot slightly in trying to stop at a given bank angle.

ILS Beam Tracking

Small corrections on the localizer are between easy and moderately difficult. I'd call it moderately easy, and they would be easier if you could initiate bank angle sooner and if you could stop the bank angle more precisely where you want it, but it's not too bad. Glide slope is moderately difficult because of the lack of precision in controlling the pitch angle and the difficulty in controlling the airspeed. So the airspeed is moderately difficult to control.

Ability to Make Small Bank Angle Corrections

To make small bank angle corrections is moderately easy. It's not as good as it could be because of the time required to get the wing started to move in roll and because of the difficulty in stopping it precisely where you wanted.

Ability to Pick Up a Wing

Adequate.

Roll Authority

The roll authority is adequate.

Trim Changes

There is a pitch trim change with power. It's not very large, but it's noticeable. I saw no other pitch trim change that gave me trouble. The ability to compensate for that trim change was between easy and moderately difficult. It would be easier if I had precise control of the pitch angle, which I don't.

Would Fatigue be a Significant Factor?

I would call the fatigue factor not very significant. With the lighter forces with small corrections, it's easier and I do not think I'd be unduly disturbed by flying this for hours.

Workload

I consider the workload to be moderate.

Most Objectionable Features

The difficulty in getting the airplane moving easily, stopping it precisely, making the pitch angle we want, when we want it, and stop the pitch angle right where we want and controlling airspeed are most objectionable.

Turbulence Level on the Approach

The turbulence was light to moderate, and slightly distracting. It added to the workload. It degraded the performance somewhat but it was an acceptable task performance. I think it would be a "D".

Performance of Various Segments of the Mission

The ILS capture could be done fairly well. It required quite a lot of attention to do that right while you're trying to take care of the longitudinal characteristics of the airplane but you could do it. On the tracking, the localizer was done quite well. Tracking the glide path was not done as well. The ability to line the airplane up with the runway VFR was quite good.

Configuration Rating

I would call this a 4. It's satisfactory if I had to take it the way it was, but it should be better. The objections I think are not too bad and the main thing is that the critical feature, the ability to finally line the airplane up, was pretty good. If that were the only thing, I would call it a 3 but the ability to fly the airplane during the rest of the maneuver had these deficiencies which I've been talking about and that degrades it to a 4. The things that kept it from being better were the time required to pick a wing up and get it going, for small disturbances, and the wallowing tendency in heading.

Pilot B Configuration S-2 Flight No. 93
C_{ℓ_r} = +3(BL) = +.63/rad

General Comments

Airplane felt pretty good. There is quite a bit of yaw due to roll. However, there is very little roll due to sideslip. The yaw damping seemed to be pretty good, it's damped about three or four oscillations, looked like about an 8 to 10 second period. Longitudinally, it was also fairly well damped. Again, it appeared to be near neutral; with putting in a doublet the nose tended to hang up; putting nose down, nose up and releasing the controls, the nose tended to stay up rather than come back down to the neutral point.

Coordination in Turns

Actually the turns were initiated with aileron only and no rudder so there was no rudder used initially and then the secondary rudder was used with the turn which seemed to be a help. In the steady state turns I didn't use the rudder. Turning on section lines was pretty easy to accomplish. However, on instruments, turning to a heading as selected on the HSI and tracking that heading was more difficult. I think this is probably due to the yaw due to roll. Yaw due to roll makes the heading a little more difficult to hold on the HSI.

Initial Response to Aileron-Only Input

Initial response to the aileron input was an adverse yawing motion of about 5 or 6° if you rolled right into about a 30° turn. I wouldn't say that the nose hangs up. It actually went left as the right turn was initiated. Lateral acceleration not really a good assessment on that.

Ease of Achieving Desired Bank Angle

Bank angle was moderately easy to achieve. I was able to roll out on the desired bank angle without excessive under or overshoot.

Oscillatory Characteristics (Lateral-Directional)

Looking at first open loop, I covered those in the general comments. Initially, sideslip induced very little roll, very small correction was required in aileron to keep the wings level. Rudder kicks gave a fairly well damped oscillation. The aircraft was fairly well damped directionally, and the period looked like about 8 to 10 seconds. There was about 3 or 4 cycles that I could see before it damped out. Longitudinally it was more near neutral. Closed loop, putting in a roll, if I didn't use rudder I'd get adverse yaw, but if I used rudder, that helped in controlling in the turn. Closed loop again, the damping is fair but it wouldn't be enough for a normal operation. Controlling the oscillations that I got was with rudder and it was moderately easy. Oscillations were excited mainly with lateral inputs and it was pretty easy to excite it with ailerons. Just for turning to headings I used aileron only, and in tracking down the runway, I used both aileron and rudder. Spiral stability appeared to have some effect. I would say the airplane is pretty spirally unstable, and tended to diverge but it was not difficult to control.

Control Feel

The forces are too heavy on all three axes. I'd decrease the breakout forces and also reduce the gradient because it's too large. Travel is getting reasonable on all three axes but I would still consider it too large on both aileron and elevator. Breakout forces I've already mentioned, too heavy.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

I didn't notice that longitudinal inputs caused an excessive lateral-directional oscillation.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

No comment.

ILS Beam Capture

ILS beam capture is moderately difficult, more difficult on the localizer than glide slope. Two reasons, one is the yaw due to roll but it also appears -- the bank steering bar sometimes would give opposite steering directions to the way we needed to go to correct the center line.

Ease of Rolling Out on Desired Heading

Using the flight director, it was moderately difficult on heading both VFR and IFR. Bank angle control would be between easy and moderately difficult.

ILS Beam Tracking

ILS beam tracking on the localizer again was moderately difficult and on the glide slope about the same.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections were easy to moderately easy. I think it would still be even easier with the force gradients I recommended.

Ability to Pick Up a Wing

The ability to pick up a wing with the force gradient used today is adequate.

Roll Authority

Roll authority I would say, is between adequate and just barely adequate.

Trim Changes

Nothing unusual, it is what would be expected for the speed and power changes, and it was easy to correct for trim changes.

Would Fatigue be a Significant Factor?

The workload would be noticeable with this flight condition or with this model at the end of the long flight. A precise approach would be difficult while under fatigue.

Workload

I consider the workload moderate.

Most Objectionable Features

The yaw due to roll seems to be the most objectionable thing and nothing stands out as particularly good.

Turbulence Level on the Approach

Turbulence is not significant so that would be about an "A" rating.

Performance of Various Segments of the Mission

Performance level would be considered average, or maybe slightly less than average -- average minus.

Configuration Rating

The configuration rating for this would be between 4 and 5.

Pilot A Configuration S-3 Flight No. 114

C_{l_r} = +2(BL) = +.42/rad
$C_{n_{\delta_a}}$ = +3(BL) = -.0345/rad

General Comments

It's a pretty good configuration. Requires some rudder to help straighten out the turn and not very prompt response in the turn which leads you to generate a small residual limit cycle oscillation in roll. It has a little lateral acceleration, but not much and in general pretty good. The longitudinal characterisitcs, no better than they've been, but that's still not very good.

Coordination in Turns

You use a small amount of rudder with the turn. Secondary, you use a rather moderate amount of rudder, not so much with the turn as with aileron, and gradually release the rudder to damp the Dutch roll and this is easy to do, you sense lateral acceleration and keep it small. I thought it was easy and natural to do. No steady state rudder. I thought the turns were quite easy. They were easy because you didn't have much lateral acceleration, a little but not much and the use of the rudder to help things out was straightforward and easy to predict, easy to understand, and in general, it was pretty good.

Initial Response to Aileron-Only Input

Yawing motion goes just a little bit the wrong way first, but not much and easy to add rudder, short time that it hangs up. The lateral acceleration is small, but still perceptible, but pretty darn small and I would not complain about this amount of lateral acceleration. I did notice it when I was IFR making small sharp corrections to the bank angle to keep the flight director needle centered or to keep the heading right where I wanted it. There was a small feel from the lateral acceleration.

Ease of Achieving Desired Bank Angle

I would say to acquire the desired bank angles, moderately easy or pretty easy, I don't care. And it's because of its predictability and of how much rudder you need. It would be better if it didn't have quite such a long lag to get started in the first place which I attribute to τ_R. You have a slight overshoot tendency, not open loop but closed loop. Not very great, but you can see it, attributed to PIO.

Oscillatory Characteristics (Lateral-Directional)

Open loop, same as usual, small roll, almost none, but some. Moderate yawing motion, longish period, quite heavy damping. Closed loop - you get a small oscillation in roll, driven by the pilot when a small tight correction is needed. Otherwise you didn't feel any overshoot. So the damping of the closed loop motion was pretty good. In other words this usually didn't persist very long unless you needed another correction in which case you get another overshoot. Damping the open loop is quite heavy. The oscillation was controlled with the aileron just by relaxing the aileron, you use rudder to fix the Dutch roll on the turn recovery. The oscillation was excited by the use of the aileron and that's about all. Of course you could do it with the rudder, but that would be pretty silly. Turbulence did not seem to excite it very much except by requiring a correction in ϕ which required some aileron and some roll rate. The spiral did not seem to influence me one way or the other. Didn't notice it. Did not come into play here.

Control Feel

The forces, the aileron's a little light, the rudder is good, the elevator is good. The travel, all of them are reasonable. If anything the aileron is a little bit small, would have liked a little more. Maximum travel - didn't notice or never reached it is really what it amounts to. Breakout forces are good, on aileron, rudder and elevator.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

We didn't see much cross-talk from the lateral-directional, from the longitudinal to the lateral-directional.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Only by distraction, due to requirement for lateral-directional. Didn't see any direct cross-talk.

ILS Beam Capture

Localizer capture, I thought it was really pretty easy. I could fly this airplane quite well and could capture the localizer quite well. The air is fairly smooth today, but a little turbulence. Glide slope, moderately difficult, you have to pay attention to the glide slope because of the poor longitudinal characteristics of this airplane. The relatively spongy feel and lack of precision in sending the pitch angle to what you want.

Ease of Rolling Out on Desired Heading

I thought it was pretty easy to roll out on the bank angle, but small overshoots driven by the pilot and the heading both VFR and IFR, to hit it exactly was moderately difficult. The Dutch roll interfered here.

ILS Beam Tracking

To track the localizer, I found relatively easy. Glide slope and airspeed moderately difficult because of the poor longitudinal characteristics. The localizer was moderately easy because of the pretty good ability to control the bank angle. The small overshoot, didn't really stop you from doing the job, that is, it made it a little less predictable as to what you were doing, but it didn't stop you from making a good average on the bank angle and I thought I could fly it pretty well.

Ability to Make Small Bank Angle Corrections

Small bank angles were somewhere between easy and moderately easy or maybe moderately easy. They'd have been better if τ_R were smaller and better if no overshoot in ϕ, and better if Dutch roll was faster period so you can predict it better.

Ability to Pick Up a Wing

The ability to pick up a wing was adequate, it was good. And did not excite the Dutch roll too much when you did that.

Roll Authority

Maximum roll rate was adequate or more than adequate.

Trim Changes

Trim change - small trim with respect to power. No other trim change that I saw. They were easy to compensate.

Would Fatigue be a Significant Factor?

Fatigue would not have been a factor. I could have flown this for a long time without troubles, as far as lateral-directional is concerned. Pitch would be more of a problem.

Workload

Workload, I'd call moderate because of the relatively good lateral-directional characteristics.

Most Objectionable Features

The most objectionable feature is the longitudinal motion and in the lateral-directional, the most objectionable feature is the low period or long period of the Dutch roll, the small overshoot in ϕ for tight control and the requirement for rudder. None of these are too terribly bad, they're all acceptable, but those are the objectionable features. Nothing was outstandingly good.

Turbulence Level on the Approach

The turbulence level was light and on our scale I would call it a B.

Performance of Various Segments of the Mission

I thought I performed the various segments pretty well. You could fly headings pretty well, not, that was the worst, you could stop and settle down on a required heading with no error, that was probably the least good point of it. Then capturing the localizer I thought was pretty good. Flying level was moderately good. The good lateral-directional characteristics made it easier to do the longitudinal task. The localizer tracking, I thought I did a pretty good job on it and furthermore, knew what I was doing. I had enough time left over to pay attention to how the whole problem was coming and rather than just blindly staring at the flight director, that being all you could do, I felt I had time left over to keep track of what was going on. Tracking the airspeed and the glide path was pretty good, however, again I think due primarily to the better lateral-directional characteristics which permitted me to spend more time on the rather poor longitudinal characteristics of this airplane. Even when we got down low and things got more complicated as you approached the minimums, I can still do, I thought, a pretty good job. Following a heading during the offset approach was not easy because it was hard to acquire the heading when they said turn 2° to the right or 5° to the left, it wasn't easy to stop the airplane on that heading and find it would stick there. The Dutch roll would be prominent and it wasn't easy to damp out. So, this was not as good, but even so I could do a fairly good job there. Flying down the runway after breaking out, lining up with the runway and staying lined up was pretty easy. I felt I could have stayed lined up with the runway and put it on the runway with good assurance that I would stay on the runway, and changing from the centerline to the edge of the runway and back to the centerline could be done fairly well. Would be better if the airplane would respond faster, the long τ_R is not so good, the long Dutch roll is not so good, but the fact that you could use the rudder in a way which was natural and it did not require special thinking to put in the right rudder was, certainly helped to make it good. So I felt I could do a pretty good job of flying it down the runway and re-establishing my line-up if I needed to.

Configuration Rating

The rating, it's controllable, no doubt. You can certainly do an adequate job with a tolerable workload. Is it satisfactory without improvement? Yes, I'd say so and it has some mildly unpleasant deficiencies, somewhere between a 3 and a 4. I think I'd take the airplane without improvement, the way it stands. If you wanted to improve it, I'd like it better by making the Dutch roll a little faster and by making τ_R a little faster, but it's not a bad airplane. So I think I'd still call it a 3 and the thing that dictated this rating was the predictable lateral-directional characteristics, the predictable use of the rudder, the small lateral acceleration which didn't interfere very much and the thing which kept it from being a better rating was the long Dutch roll period which made the heading changes come in after you were expecting them to come in and also the time required to pick the wing up. The τ_R is long enough so I don't like it too much. But you can cope with it all right, I would never call it a better rating. If I were going to modify this rating in any direction, I'd modify it toward a 4. The overall rating including the longitudinal would be a 5. It requires considerable pilot compensation to cope with these longitudinal characteristics, but because the lateral is better than it has been in some other configurations, it allows you more time to do the longitudinal and so the rating for the overall is not as low as it might otherwise be, otherwise it would be a 6.

Pilot A | Configuration S-5 | Flight No. 115

$C_{n_{\delta_a}}$ = +6(BL) = -.069/rad
C_{ℓ_r} = +2(BL) = +.42/rad

General Comments

Corrections in the localizer are particularly hard to make it stay still on a flight path down the runway, to fly over a line on the runway, because when you make a bank correction, it slides off sideways a significant amount, not as much as the maximum I saw in the Ames simulator but still it resembles that type of behavior. I don't quite see how you'd get it without having a large Y   which seems improbable, but nevertheless, that's what it does and that's bad.

Coordination in Turns

You use a little rudder in some direction. I never could figure out which way it was, so use some small rudder and I think it was against the turn but I don't really know. You could do this in up-and-away flight in making corrections and then as soon as you get the airplane going, you have to use some secondary rudder and again I don't know whether it's with or against because it isn't really either. It's to damp the motion. You can feel the slow rudder motion to damp the Dutch roll. So it isn't just mechanically with the turn. It isn't just mechanically with the ailerons. It requires some fancy foot work and you can do it if you have nothing better to do. In up-and-away flight, you can significantly decrease the lateral acceleration to the cockpit by doing this but as soon as life gets complicated you forget what you are supposed to do and you have to give up. You do use the rudder to help damp out the Dutch roll even in the ILS situation. No steady state rudder. Turns were moderately difficult because of this sloshing about and that induces a closed-loop stability, in roll, the pilot keeps oscillating the airplane in roll at a frequency that is higher than the Dutch roll frequency and I didn't like that.

Initial Response to Aileron-Only Input

The airplane seems to turn I think the wrong way first, but I don't really know and then you've got a tremendous lateral acceleration and a tremendous sloshing of the nose out in the wrong direction. By using sufficient rudder you can keep the Dutch roll from producing these large sideslips. If you do it with no rudder at all you do get these very large sideslip angles and the nose sloshes all around. In fact we popped the system on the basis of maximum side force surface travel. I don't recall which way it goes. I carefully sorted it out during the maneuvering and I forgot. You always give rudder with aileron or you always give rudder against aileron or something like that. It requires closing the loop on the spot, you don't think mechanically this or mechanically that, that's why I can't remember it. If you wanted me to, I could go back and find out again but I don't think that it is worth it. Furthermore the timing changes. The initial response is what appears to be yaw due to aileron and that comes in rather quickly as you put in the aileron quickly so does the yaw due to aileron. So the rudder to correct that has to come in pretty quickly and that excites the Dutch roll and then you have this much slower response to the Dutch roll because the Dutch roll is low frequency and so now you have to suddenly change your rapidity of moving the rudder, this gets to be a pretty complex task. Again, it's one you can do if you have nothing better to do but as soon as life get's complicated and you are flying the whole ILS task you just stop doing that and you help out the damping of the Dutch roll with the rudder and that is all that you do with the rudder. Lateral acceleration is large but not extreme, relatively smooth.

Ease of Achieving Desired Bank Angle

It's a little bit difficult to achieve the desired bank angle. You tend to overshoot and I kept getting complaints from the flight crew on banking too steep. I hadn't intended on banking too steep in making turns. I'd rock up to what I would think is a reasonable size bank angle, go off in my scan pattern to pay attention to something else, come back and find that I am now banking steeper than I was before. Not, I think due to the spiral, I think it is due to the Dutch roll. As you would bank it up and the next time you come around you bank some more in the Dutch roll and you hadn't counted on that happening. I didn't like that. You do overshoot in the roll mode. The airplane sits there and oscillates in yaw which is annoying but not disabling in the up-and-away flight but it is pretty bad on the final part of the ILS when heading angle is pretty important to you and when the flight director is taking heading angle into account in its computations. So that as you would attempt to center the needle on the flight director, using bank angle, which is the way you would normally fly it, that induces some yaw or some rate of turn and that influences the behavior of the flight director needle that you were trying to center. So, you end up again with a closed-loop instability and the needle just sits there and oscillates down the ILS. However, you can make the mean stay pretty much where you want it so you can in fact fly the ILS.

Oscillatory Characteristics (Lateral-Directional)

The open loop is the same as usual, small roll, moderate yaw, long period, heavily damped Dutch roll. Closed loop you get an oscillation in roll due to closed loop driving it with the ailerons and they you get an oscillation in yaw which is significant due to aileron used to "control" the roll angle. As you are trying to drive the roll you induce an oscillation in roll and that induces a bigger oscillation in yaw. The damping of the closed loop is clearly not enough. The only way you get rid of it is to get the mean good enough and then just let go and then the heavy damping of the normal Dutch roll will take over and then a lower frequency, and that is confusing because it suddenly changes the frequency, will damp the motion out. The open-loop damping is good, by Dutch roll standards. It was controlled with the aileron and that didn't help very much. The rudder was not useful except to finally damp the Dutch roll, then you did use it. For the whole initial business you couldn't use the rudder, it wasn't possible to figure out a time history of what to do with the rudder that was consistent in that you could do without taking a reasonable amount of time away from your primary task of flying the ILS. So the oscillation was excited by the aileron, although you could do it with the rudder, you didn't, the turbulence didn't excite it much. The turbulence doesn't induce much roll and so the turbulence didn't seem to make much difference. It was the pilot driving the thing with the aileron. The rudder, well all the controls were used. The spiral didn't seem to influence the motion much, I didn't particularly notice the spiral.

Control Feel

The aileron was good, the rudder was good, the elevator good. The aileron feels kind of heavy because you are using it so much but I am sure that if you had it lighter you would disturb the airplane still more, so this compromise is good as far as I am concerned. Travel was good for all three, maximum travel was never reached so I can't discuss that. The breakout forces seemed good to me in the aileron, rudder and elevator. Rather heavy breakout in the aileron that is what I want, because if I had zero breakout than I had trouble with the trimming and I had to keep trimming it. If I have some breakout, really some friction, then I can put the aileron where I want it and the friction will keep it there and this is worthwhile for me.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

Yes. Primarily in the sense of attention diverted by lateral-directional task so the longitudinal task done poorly. Not enough time to keep up with it.

ILS Beam Capture

The localizer was no more than moderately difficult because of this oscillation. It really wasn't too difficult. I call it only moderately easy. Glide slope was moderately difficult because of the lousy longitudinal characteristics of this airplane which we discussed before and I'm not going to talk about them again.

Ease of Rolling Out on Desired Heading

To roll out on a bank angle is moderately difficult due to oscillation from aileron inputs and to stop on heading VFR or IFR, but especially IFR was moderately difficult due to Dutch roll, making it slide back and excited by the , and the same was true for the VFR, we had the same problem. The VFR heading was not very well handled either.

ILS Beam Tracking

To track the localizer was again, moderately easy, although you had all this oscillation and all this bad stuff I've been talking about. The mean could be controlled fairly well so you ended up being able to fly the localizer fairly successfully, although it wasn't easy. The glide slope was moderately difficult because of the difficulty in setting the pitch angle and making it stay put. The airplane always tends to oscillate in pitch, not due to open loop light damping, but due to the slow long period with rather great elevator effectiveness so that it is easy to overdrive and then you see nothing happening in the beginning. Then the pitch rate goes off, you try to stop it and you overshoot the other direction. You always end up with a little oscillation that shows up particularly in our gamma presentation, that is it's an expanded scale and it really shows up there that you can't hit the pitch angle and hold it. Airspeed is difficult the way it always has been on this airplane. Power is hard to set and all that stuff.

Ability to Make Small Bank Angle Corrections

Small bank angle corrections are moderately easy but will result in a small limit cycle oscillation in bank angle, and I don't like that. But you can make these corrections and the mean will come out about right. However, the yaw angle will skate around for a while so you don't know what you ended up with in terms of heading correction.

Ability to Pick Up a Wing

The ability to pick up the wing, this is another one just like the last one I flew where the roll rate is adequate but the large yaw, large n_y , large beta are bad, and hard to correct using rudder. So I'd like to call it inadequate, not because it won't roll, but because of this really lousy sloshing. The wing will come up all right, but then you get this large yaw so it is hard to say how to define that one so I'll give you both answers.

Roll Authority

Roll authority is adequate or more, I think we have more roll rate than we need.

Trim Changes

Small trim changes with respect to power. I saw no trim change with respect to anything else, and it's easy to compensate.

Would Fatigue be a Significant Factor?

I would consider these characteristics would influence you on a long flight, and would fatigue you. I think that it is a bad characteristic to have to fight the airplane all the way and I'm sure that this would happen.

Workload

I would consider the workload to be large primarily due to computation to stay ahead of the motion. The lateral-directional interferes with gamma control and V control and so you have to keep forcing yourself to work hard running round and round the scan pattern to make it work so I consider that a large workload.

Most Objectionable Features

The most objectionable feature clearly is the sloshing about, the lateral acceleration and the yaw accelerations, the yaw motion due to the aileron input. Then the long period Dutch roll which is quite different from the rather quick response of the yaw due to the aileron is distracting and harder to predict than if they were at the same frequency, I think. Nothing stood out as particularly good. The longitudinal motion is still poor just as it has always been.

Turbulence Level on the Approach

The turbulence I would call light. Occasionally it got to be moderate, however, it bothers you more just because the airplane is a trouble maker and so anything bothers you more, so it requires more effort and I would call it moderate. So it is probably a D although the same turbulence with a different configuration, a better one, would be rated probably a B or a C.

Performance of Various Segments of the Mission

Nothing was done too well, nothing was done too badly. The worse were the lining up with the runway and flying headings. So to fly a heading just on the downwind leg was not done very well. It was hard to keep it even within 5 degrees. You set it and then after a while you would be off and it would be hard to make the correction due to the low Dutch roll frequency. That was bad news. It interfered with your altitude control just by distracting you. Then the ILS capture wasn't actually too bad. The ILS tracking wasn't too bad. I didn't like this lateral acceleration and didn't like the oscillation in roll but I could fly the mean fairly well and this did permit me to do the job moderately well. The glide path, same way, I could do a reasonably good job, fairly good job, distracted by this lateral-directional stuff. The lineups could be done fairly well, if you were already lined up you could continue down the runway but you didn't have a good feeling that you could make it stay there. The reason was that aileron motions not only produced some yawing motion in the sense of angular motion but they produced a pronounced lateral translation and even small aileron inputs produced an effect that you could see. This lessened your confidence in your ability to proceed down the runway. If you made large corrections you realized that you were correct that the airplane would slide sideways off the runway, you would just lose that whole approach and you had to start over again. However, I was still able to bring the airplane down to minimums with things under fairly good control so it wasn't too terrible there. But picking up the wing where you had this large sloshy motion, this moving sideways off the side of the runway when fixing the bank angle I think were the bad things on this configuration. The other stuff affected your ability to do the ILS, affected your ability to cope with more than just doing the ILS such as engine trouble and so on, but you just put up with the bad characteristics and accepted the mean of the motion of the airplane and it would work.

Configuration Rating

Configuration rating - this is one of those difficult ones. It's controllable, no doubt. The difficulty is deciding whether you could really do adequate performance or whether you couldn't. The reason that it is difficult to decide is that if you got things organized in the first place, and got it aimed down the runway, you could probably stick it on the runway and only complain, and if on the other hand you were not aimed down the runway so you had to make a small correction at the last minute then your tendency to slide sideways off the runway was most distressing. So then I would say, yes, you require some improvement. I don't know quite how to answer this. I'll think I'll call it a 7, it could just as well be a 6. I don't know how to answer it, but I think I will call it a 7 on the basis of the lateral-directional characteristics, namely this large yaw when picking up wing and also this tendency to slide sideways over the runway if aileron is used to correct bank angle. It is a hard one. I could produce an argument with 6, saying, well, if you have it lined up you could do this. You can fly it not too badly and if things get worse you have to go around. But I really think I'll call it a 7, you've got to make it a little better than this. The longitudinal is still poor, but it doesn't affect the rating. It's already low because of the lateral and I don't think I would take it any lower.

Pilot A Configuration S-7 Flight No. 91

C_{l_r} = +2(BL) = +.42/rad
C_{l_β} = +5(BL) = -.086/rad
$C_{n_{\delta_a}}$ = +3(BL) = -.0345/rad

General Comments

It is not a good configuration. It was not too bad either but it's hard to figure out what was right and what was wrong with it. Using the rudder made things worse. It was hard to fly really, but you could get it lined up with the runway. So it's a marginal configuration and I required an extra ILS run in order to rate it and even then it's a shaky one.

Coordination in Turns

Using rudder is a big mistake so I don't use it. I tended to use rudder with the aileron to try to help it roll out and all it would do is excite the Dutch roll. I soon found I did better to use only the aileron and accept the sloshing about which leads you to think you should use some rudder to help it, but you don't help it. Ease in accomplishing turns is moderately difficult because it sloshes laterally in a way that is hard for the pilot to relate to what's going on, and this tends to lead the pilot to use aileron to stop the roll when you want it to stop, and then applying aileron makes it slosh, and then leads you to then put in some aileron to stop that because you can't use rudder, and it gets worse so you do tend to oscillate about the roll angle that you want.

Initial Response to Aileron-Only Input

It turns the wrong way but not at first. The nose sort of hangs up at first. Then it turns the wrong way and then it turns the right way and rudder did not help. The nose doesn't hang up very long, like a second. Lateral acceleration is not particularly high.

Ease of Achieving Desired Bank Angle

Moderately difficult to get the right bank angle because there is quite a tendency to overshoot. I noticed that, as I was flying along, I tended to oscillate almost steadily at a bank angle so the overshoot is moderate and is driven by the pilot as you try to come to a certain bank angle. It's very easy to sit there and oscillate the airplane with the ailerons about the bank angle. Every time you use an aileron it disturbs the airplane that reflects not right away, in a bank angle which then you have to correct for by using some aileron which then excites the motion again. That's the reason for this overshoot. It tends to keep right on going like a limit cycle.

Oscillatory Characteristics (Lateral-Directional)

Open loop is the same as usual, small roll, moderate yaw, pretty good damping, long period which manifests itself later in trying to hold a heading or turn to a heading and stop on a heading. The overshoot is related to the

Dutch roll. Closed loop, you certainly do get an oscillation in roll. It's small amplitude but it's enough to bother the pilot and the yaw oscillates also because you're oscillating the ailerons to try to fix this bank angle to what you want, and that's annoying. Closed loop it's very nearly zero damped. You tend to keep right on operating it as a limit cycle. Rough air disturbs the airplane in roll a little bit and then you use some aileron to fix it and that leads to trouble. The aileron was used to control it. It was difficult to control. You could not use the rudder except to damp out the Dutch roll. You couldn't use the rudder to help you in and out of turns without getting into worse trouble than you had if you didn't use the rudder. You have trouble no matter what you do. So the motion was excited by the turbulence but not very much. You could excite it by the rudder all right, but that wasn't the problem. The aileron excited it all the time. The spiral did not seem to be a problem to me.

Control Feel

The forces feel heavy but probably all right on the aileron because I used the aileron quite a bit so I complained about the heavy forces. Rudder seemed all right, somewhat on the heavy side, elevator seemed all right, somewhat on the heavy side. The gradients seemed reasonable for all three surfaces. The travel seemed reasonable for all three surfaces. The breakout forces are present in the aileron and elevator; don't know about the rudder. And I would consider them acceptable.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

Saw no interaction between the longitudinal and lateral-directional.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motion?

Yes. Partly, I think, that you may actually inadvertently disturb the pitch when you're putting in all these aileron inputs and partly that the distraction of flying the aileron task made the longitudinal task noticeably poorer.

ILS Beam Capture

Capturing the localizer was moderately difficult because of this imprecise bank angle control and the sloshing that came with it which you didn't know quite what to do about. Capturing the glide slope was moderately difficult for the similar reasons that I just mentioned in the preceding comment.

Ease of Rolling Out on Desired Heading

To roll on a bank angle was moderately difficult because you tended to overshoot the bank angle. You could hit a mean bank angle pretty well but you're always overshooting and with this rather long initial time to get the bank angle or to get the roll rate, you didn't know quite what bank angle you were going to end up with or quite what the effect of the correction will be and you certainly tended to get a limit cycle oscillation in bank angle. I noticed it as I was flying that I would tend to wallow down the localizer. These are not Dutch roll frequencies. They're higher than Dutch roll frequencies, shorter period. Heading IFR was moderately difficult but not very difficult. You just turned to the bank angle and anticipate a little bit and let it oscillate and it would settle down on more or less the right one but it certainly was not easy. The VFR was really sort of difficult to figure out what to do because the temptation to use the rudder was very great but it was a mistake. So, I would call it moderately difficult. You had to really pay attention to get the heading to come out, somewhere between moderately difficult and very difficult, if we count the runway alignment, that is if you want to get right on the heading when you wanted, that is not just in time but in lateral position so that you're going right down the runway centerline, it was possible but it was pretty hard.

ILS Beam Tracking

Ability to make small corrections--on the localizer it was moderately difficult because of the tendency to overshoot the bank angle as you develop this sloshing motion which then influences you to do something different with the ailerons. The glide slope was moderately difficult because of the distraction of the lateral task and also the poor longitudinal airplane to start with. Airspeed was moderately difficult for these same reasons.

Ability to Make Small Bank Angle Corrections

Moderately difficult because of the time to get started, the overshoot tendency, the bad oscillation in yaw which made you do something with the aileron to try to stop it because the rudder was a poor device for stopping this motion. It's interesting if you use the rudder to help roll out on a heading or pick up a wing. You would help it initially but then after the wing was back up, instead of the motion just settling down on a heading angle, it would slide way out. In other words, you didn't excite the Dutch roll as much if you just use aileron and so you ended up having to say, I cannot use the rudder in this airplane.

Ability to Pick Up a Wing

The ability to pick up a wing was adequate but poor due to yaw motion. The wing would come up but then you would excite this yawing motion which you were unable to compensate with rudder.

Roll Authority

The roll authority was certainly adequate.

Trim Changes

Small pitch trim change with power. Corrections, under these circumstances, were somewhere between easy and difficult because the lateral-directional task got in your way so I found that I was frequently muffing the corrections of power.

Would Fatigue be a Significant Factor?

Annoying, but I don't know how fatiguing it would be. I think I would count it as moderately fatiguing, that it would not be a good one to fly for hours but certainly a possible one.

Workload

Workload is relatively large counting the thinking and the physical motion too. You had to pay attention to this configuration, and not a nice one.

Most Objectionable Features

The objectionable feature is this sloshing in yaw when you apply some aileron for which rudder did not seem to be a good compensating control. And the other objectionable feature is the usual criticism with the longitudinal motion, and a third objection is this relatively longish time to start the roll motion going or to stop it.

Turbulence Level on the Approach

The turbulence was light, just occasionally moderate. It interfered quite a bit, so it really made me work. I think I would call it "F". Somewhere between "E" and "F".

Performance of Various Segments of the Mission

Not very good performance on any segment but you could do the whole task including the lineup with the runway, but not good.

Configuration Rating

Adequate performance, just barely adequate and it certainly warrants improvement. I consider these very objectionable but tolerable deficiencies. But it's a lousy airplane and it certainly requires extensive compensation but you could still do the tasks. So that leads to a 6 and the thing that hurt was this sloshing about in yaw which I could not correct for and this interfered with my performance on the longitudinal motion and I didn't like that. I found the longitudinal motion poor. Now, if we had to rate with the longitudinal also, I guess it also would be just about a 6, bordering on a 7.

Pilot C Configuration S-7 Flight No. 100

$C_{l_r} = +2(BL) = +.42/\text{rad}$
$C_{l_\beta} = +5(BL) = -.086/\text{rad}$
$C_{n_{\delta_a}} = +3(BL) = -.0345/\text{rad}$

General Comments

None.

Coordination in Turns

Rudder use is zero in primary, secondary, and steady state. It was quite easy to accomplish turns. The factors that contributed to this were a well harmonized set of derivatives. We have good coordination in turns, no proverse, no adverse yaw. Essentially a neutral spiral. A little bit of positive C_{l_β}. A good stick force gradient, no breakout, and no deadband observed.

Initial Response to Aileron-Only Input

Initial response to aileron-only input is just about right. Pretty well coordinated thing. The nose does not appear to hang up and the degree of lateral acceleration experienced was negligible. That's different from nil now. I'm not sure but what it was nil but if there was any it wasn't a significant amount.

Ease of Achieving Desired Bank Angle

Achieving a desired bank angle was easy enough. Due to the neutral spiral, you can get into a little bit of a bank angle wander when you're taking vectors close in on the approach but that's just fine. It gives you lots of maneuverability. The factors that contributed to the choice are as stated above. Overshoot tendency of bank angle in the roll mode is, I'd say, none to slight. When you're in a big airplane typically, I notice that my tendency is to make my banks rather shallow and in this one, it feels so nice that I ride on up to 30° of bank for heading changes without any concern at all. It's very confortable but as a result of its ease, there is a slight tendency to overshoot. I don't think it's an adverse comment though.

Oscillatory Characteristics (Lateral-Directional)

The oscillatory characteristics lateral-directional, I tried to excite it with aileron and made several bank angle changes of course and the oscillatory mode is negligible and so I tried to excite it with rudder but didn't really excite it. And it required no control. Spiral mode as I mentioned before was essentially neutral and very comfortable.

Control Feel

Airplane's response to control feel was very good. I think you could handle this airplane with higher gradients all right but at this level it's just about ideal. The gradient, the travel associated with these forces was quite reasonable and the maximum travel was again not observed due to system limitations. Breakout forces were good on all three modes.

Do Longitudinal Control Inputs Cause Lateral-Directional Airplane Motions?

No.

Do Lateral-Directional Inputs Cause Longitudinal Airplane Motions?

There was no cross influence of lateral-directional on longitudinal.

ILS Beam Capture

ILS beam capture was easy and glide slope capture was easy. The ease of capture I attach to not only a good airplane but being a little further down the learning curve with the system.

Ease of Rolling Out on Desired Heading

Rolling out on a desired heading was easy both VFR and IFR, and it was easy to get into a desired bank angle. The factors as mentioned above again were very, very low C_n derivatives due to aileron deflection or roll rate. Essentially no adverse or proverse yaw, a neutral spiral, and nice amount of roll control power with no breakout or deadband problems.

ILS Beam Tracking

ILS tracking I think was easy in all three modes. The factors that contributed to this choice are as stated above.

Ability to Make Small Bank Angle Corrections

Ability to make small bank angle corrections was easy to moderately easy as mentioned above. For small corrections it's easy to overdo. The airplane has really quite low roll damping, low roll stability, so that if you're not right on top of it you can overshoot your bank angle corrections but it's not really a big problem. It would be a problem if you were distracted, I suppose, close to the ground. But that's asking an awful lot. So those are the factors that contributed to that choice.

Ability to Pick Up a Wing

Ability to pick up a wing was more than adequate.

Roll Authority

The roll authority was more than adequate.

Trim Changes

The trim changes were again small to imperceptible. I might make a comment that's sort of general. The speed stability is not really very strong. This isn't a big problem, but I think it's gone unmentioned in my previous comments on all these configurations and one does have to stay in the loop with his throttles, and keep scanning his airspeed indicator to manage his airspeed. It doesn't have a lot of speed stability.

Would Fatigue be a Significant Factor?

For a cruising flight I think it's a very comfortable airplane. It wouldn't cause any fatigue at all.

Workload

The workload is small.

Most Objectionable Features

The most objectionable feature of the configuration is, there just really isn't one. I think it's a pretty good airplane all the way around. Probably the speed stability would be the objectionable characteristic if there were one and that's not part of this study.

Turbulence Level on the Approach

Turbulence level, I think for the first time we got a little bit. I think we'll call it a rating of "B" and light turbulence, maybe light to moderate.

Performance of Various Segments of the Mission

I think that performance was pretty good for the whole thing.

Configuration Rating

I'm going to give this one a rating of 2. That's good with negligible deficiencies. No real pilot compensation required. The things that might move it toward a one would be perhaps the slightly higher stick force gradient in roll, a little better speed stability, and perhaps a slightly greater roll damping or spiral stability. But these are minor comments as indicated by the rating of 2 so, all in all, I think it's a pretty good airplane.

APPENDIX VII

TABULATION OF α_g AND β_g
RMS AND MAXIMUM VALUES
SEEN ON EVALUATION ILS APPROACHES

The RMS values listed in the appendix were determined from on-line processing of the digital flight tape with an analog computer. The gust measurements are defined at the TIFS center of gravity.

NOTE: $\sigma_{\alpha_g} = \left[\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} \alpha_g^2\, dt\right]^{\frac{1}{2}}$, where T_1 corresponds to the time that the radar altitude signal was 1000 feet and T_2 corresponds to the minimum altitude achieved in the approach. Subscripts 1 and 2 on α_g and β_g refer to two separate approaches performed during the evaluation of the configuration listed.

CONFIG.	QUANTITY	PILOT					
		A		B		C	
		σ DEG.	MAX. DEG.	σ DEG.	MAX. DEG.	σ DEG.	MAX. DEG.
P-1	α_{g_1}	.84	3.0	1.0	2.8	.748	2.6
	β_{g_1}	.72	2.8	.86	2.4	.6	2.6
	α_{g_2}	.96	3.2	.69	2.2		
	β_{g_2}	.695	2.4	.60	2.0		
	TURB. LEVEL	MODERATE		MODERATE		––	
	TURB. RATING	––		B		B	
P-1 REPEAT	α_{g_1}	.566	2.0				
	β_{g_1}	.6	2.0				
	α_{g_2}	.693	2.4				
	β_{g_2}	.583	2.0				
	TURB. LEVEL	LIGHT TO MODERATE					
	TURB. RATING	C					
P-2	α_{g_1}	.92	3.0	1.16	3.2	.4	2.0
	β_{g_1}	.75	2.0	.96	3.4	.58	2.0
	α_{g_2}	.87	2.4				
	β_{g_2}	.77	2.4				
	TURB. LEVEL	LIGHT		––		––	
	TURB. RATING	D		B		A	
P-3	α_{g_1}	.51	2.0			.89	2.8
	β_{g_1}	.693	2.0			.469	1.8
	α_{g_2}	.6	2.0				
	β_{g_2}	.664	2.2				
	TURB. LEVEL	LIGHT				––	
	TURB. RATING	––					
P-4	α_{g_1}	.62	2.6			1.41	3.4
	β_{g_1}	.58	2.2			.837	2.8
	α_{g_2}	.55	2.6			1.09	3.0
	β_{g_2}	.63	2.2			.748	2.4
	TURB. LEVEL	LIGHT				LIGHT	
	TURB. RATING	D				A	

		PILOT					
		A		B		C	
CONFIG.	QUANTITY	σ DEG.	MAX. DEG.	σ DEG.	MAX. DEG.	σ DEG.	MAX. DEG.
P-6	α_{g_1}	.85	3.0				
	β_{g_1}	.82	3.0				
	α_{g_2}	1.02	2.6				
	β_{g_2}	.78	2.8				
	TURB. LEVEL	MODERATE					
	TURB. RATING	D TO E					
P-7	α_{g_1}	.47	3.0	.346	1.0		
	β_{g_1}	.53	3.0	.346	1.4		
	α_{g_2}			.346	1.4		
	β_{g_2}			.374	1.6		
	TURB. LEVEL	VERY LIGHT TO LIGHT		—			
	TURB. RATING	C		A			
P-8	α_{g_1}	1.41	5.2	1.13	2	.55	2.8
	β_{g_1}	.847	2.8	.4	1.6	.58	3.0
	α_{g_2}	1.32	5.0			.91	3.2
	β_{g_2}	.846	3.0			.80	3.4
	TURB. LEVEL	LIGHT		—		—	
	TURB. RATING	C		A TO B		A TO B	
P-9	α_{g_1}	.60	2.4	.693	2.4	.849	3.0
	β_{g_1}	.56	2.0	.693	2.4	.678	2.4
	α_{g_2}	.63	2.0				
	β_{g_2}	.59	2.6				
	TURB. LEVEL	LIGHT		LIGHT TO MODERATE			
	TURB. RATING	D		D		A TO B	
P-12	α_{g_1}	.894	3.0			.85	3.0
	β_{g_1}	.529	2			.66	3.0
	TURB. LEVEL	LIGHT TO MODERATE				LIGHT TO MODERATE	
	TURB. RATING	F				B TO C	

CONFIG.	QUANTITY	PILOT					
		A		B		C	
		σ DEG.	MAX. DEG.	σ DEG.	MAX. DEG.	σ DEG.	MAX. DEG.
P-13	$\alpha\ g_1$	.37	2.0	.748	2.0		
	$\beta\ g_1$	.60	2.6	.346	1.4		
	$\alpha\ g_2$	.55	2.4	.663	2.0		
	$\beta\ g_2$	.68	2.8	.49	1.4		
	TURB. LEVEL	LIGHT		—			
	TURB. RATING	D		A			
P-14	$\alpha\ g_1$	.87	2.8			.34	1.4
	$\beta\ g_1$	.66	2.0			.4	1.4
	$\alpha\ g_2$	1.1	3.0			.63	2.8
	$\beta\ g_2$	.66	2.0			.41	1.6
	TURB. LEVEL	MODERATE				NONE	
	TURB. RATING	E				A	
P-16	$\alpha\ g_1$	.81	2.8				
	$\beta\ g_1$	.59	2.0				
	$\alpha\ g_2$	.72	3.0				
	$\beta\ g_2$	.72	3.8				
	TURB. LEVEL	LIGHT					
	TURB. RATING	D					
S-1	$\alpha\ g_1$	.846	3.0	1.04	3.4		
	$\beta\ g_1$	.749	2.8	1.02	3.0		
	$\alpha\ g_2$			1.08	3.2		
	$\beta\ g_2$			.98	2.4		
	TURB. LEVEL	LIGHT		—			
	TURB. RATING	D		D			

		PILOT					
		A		B		C	
CONFIG.	QUANTITY	σ DEG.	MAX. DEG.	σ DEG.	MAX. DEG.	σ DEG.	MAX. DEG.
S-1 REPEAT	$\alpha\ g_1$	.63	2.0				
	$\beta\ g_1$	.66	2.2				
	$\alpha\ g_2$	.52	2.6				
	$\beta\ g_2$	.87	3.2				
	TURB. LEVEL	LIGHT					
	TURB. RATING	D					
S-2	$\alpha\ g_1$	.85	2.0	.447	1.4		
	$\beta\ g_1$	.66	2.0	.374	1.0		
	$\alpha\ g_2$	.94	2.0	.51	2.2		
	$\beta\ g_2$	.53	1.6	.40	1.4		
	TURB. LEVEL	LIGHT TO MODERATE		--			
	TURB. RATING	D		A			
S-3	$\alpha\ g_1$	.50	2.2				
	$\beta\ g_1$	.58	2.0				
	$\alpha\ g_2$	.40	1.4				
	$\beta\ g_2$	.49	2.0				
	TURB. LEVEL	LIGHT					
	TURB. RATING	B					
S-5	$\alpha\ g_1$	.69	2.0				
	$\beta\ g_1$	.58	2.4				
	$\alpha\ g_2$	.83	3.2				
	$\beta\ g_2$	.63	2.4				
	TURB. LEVEL	LIGHT TO MODERATE					
	TURB. RATING	D					
S-7	$\alpha\ g_1$	.91	2.4			.75	2.4
	$\beta\ g_1$	.826	2.2			.63	2.8
	$\alpha\ g_2$	1.13	3.0				
	$\beta\ g_2$	.76	2.4				
	TURB. LEVEL	LIGHT TO MODERATE				LIGHT TO MODERATE	
	TURB. RATING	E TO F				B	

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13. ABSTRACT

An in-flight research program on the handling qualities of Class III airplanes in the landing approach was conducted using the USAF/CAL Total In-Flight Simulator (TIFS) airplane. This was the first research program utilizing the TIFS airplane. For this program, the TIFS was used in the model-following mode and its capability as a research facility for handling qualities investigation was clearly demonstrated. The Phase I research program discussed in this report consisted of an investigation of lateral-directional handling qualities. A baseline configuration was defined by a set of stability and control derivatives provided by the Air Force. The experiment was based on the evaluation of this configuration and other configurations defined by changes in stability and control derivatives from the baseline values. Seventeen different configurations were evaluated utilizing 3 different pilots. A total of thirty six evaluations was performed. For the configurations evaluated (typically characterized by a low frequency Dutch roll mode with low roll to yaw ratios and an unstable spiral mode), the indicated level of handling qualities defined by the $\Delta\beta_{max}/K$ requirement (3.3.2.4.1) of MIL-F-8785B(ASG) correlated quite well with the pilot ratings obtained in this investigation. The data obtained in this program indicates the need for modification of the lateral-directional handling qualities requirements of MIL-F-8785B(ASG) for airplanes with long period and low roll to yaw ratio Dutch roll dynamics, with unstable spiral mode, in Flight Phase Category C.

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